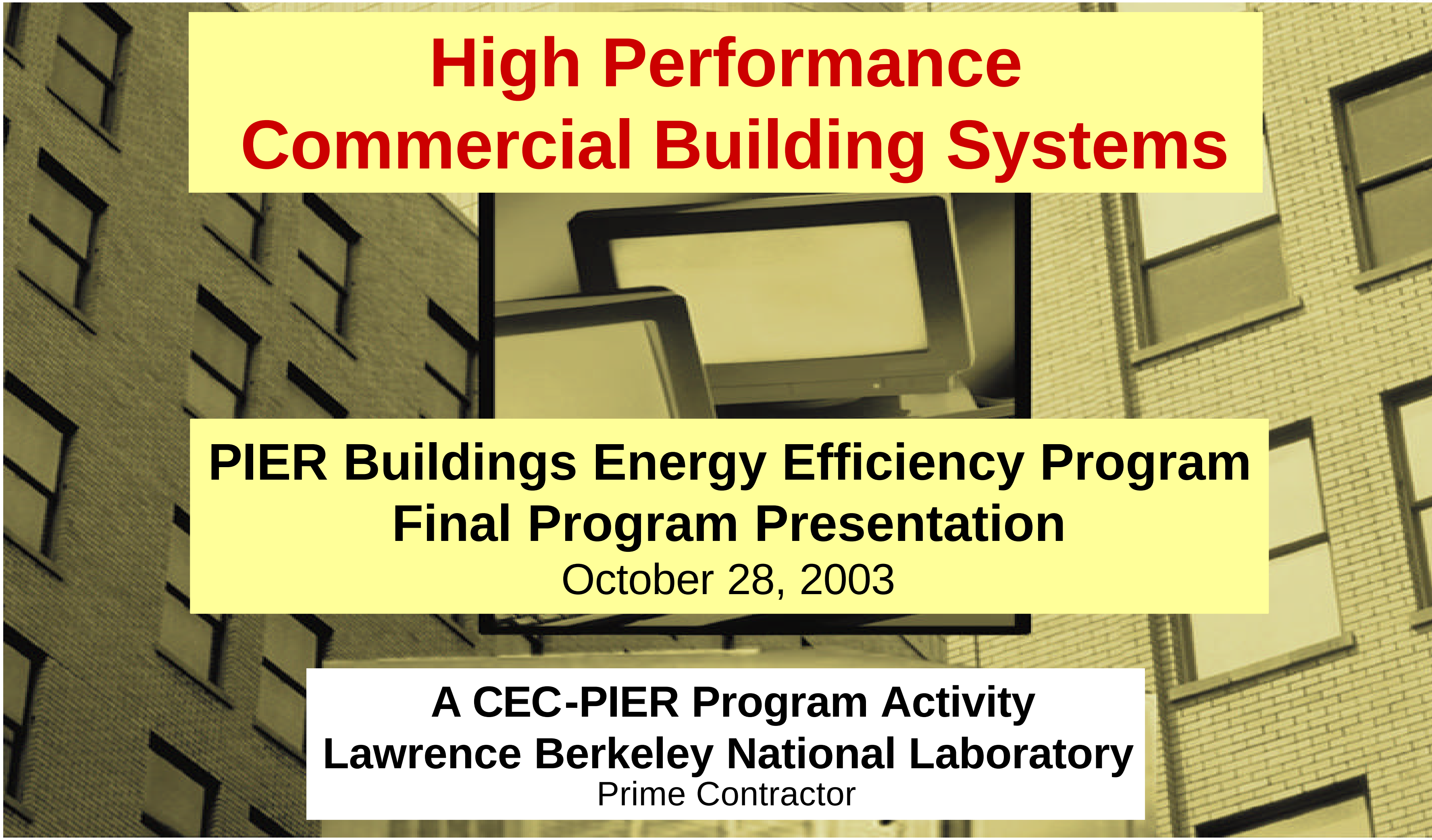


High Performance Commercial Building Systems

PIER Buildings Energy Efficiency Program
Final Program Presentation

October 28, 2003

A CEC-PIER Program Activity

Lawrence Berkeley National Laboratory

Prime Contractor

CEC PIER Program Motivation

- Commercial Buildings:
  - ~ 33% of all California electricity consumption
  - ~ 40% Impact on load shape and peak electricity
  - Major impact on public health and productivity
- 'Slow to Change' building design & operations practices
- Progress has been made but measured savings are still below technical and economic potentials

Broad HPCBS Program Goals

Provide enabling technology and tools to reduce commercial energy use and demand by 20% beyond business-as-usual, by:

- **Developing & deploying energy saving technologies, strategies, and techniques**
- **Improving commercial building design, commissioning, and operating practices**
- **Improving the health, comfort, and performance of occupants**
- **Conforming to sound economic investment practices**

National Crosscutting “Big Issues”

- Impacts of new building systems, technology
- “Digital everything”/ubiquitous computing, sensing…
- Risk and slow diffusion rates: market push and pull
- Technology focus vs. people focus (designers, owners, occupants…)
- Changing Perspective: Occupant <-> Building <-> Grid

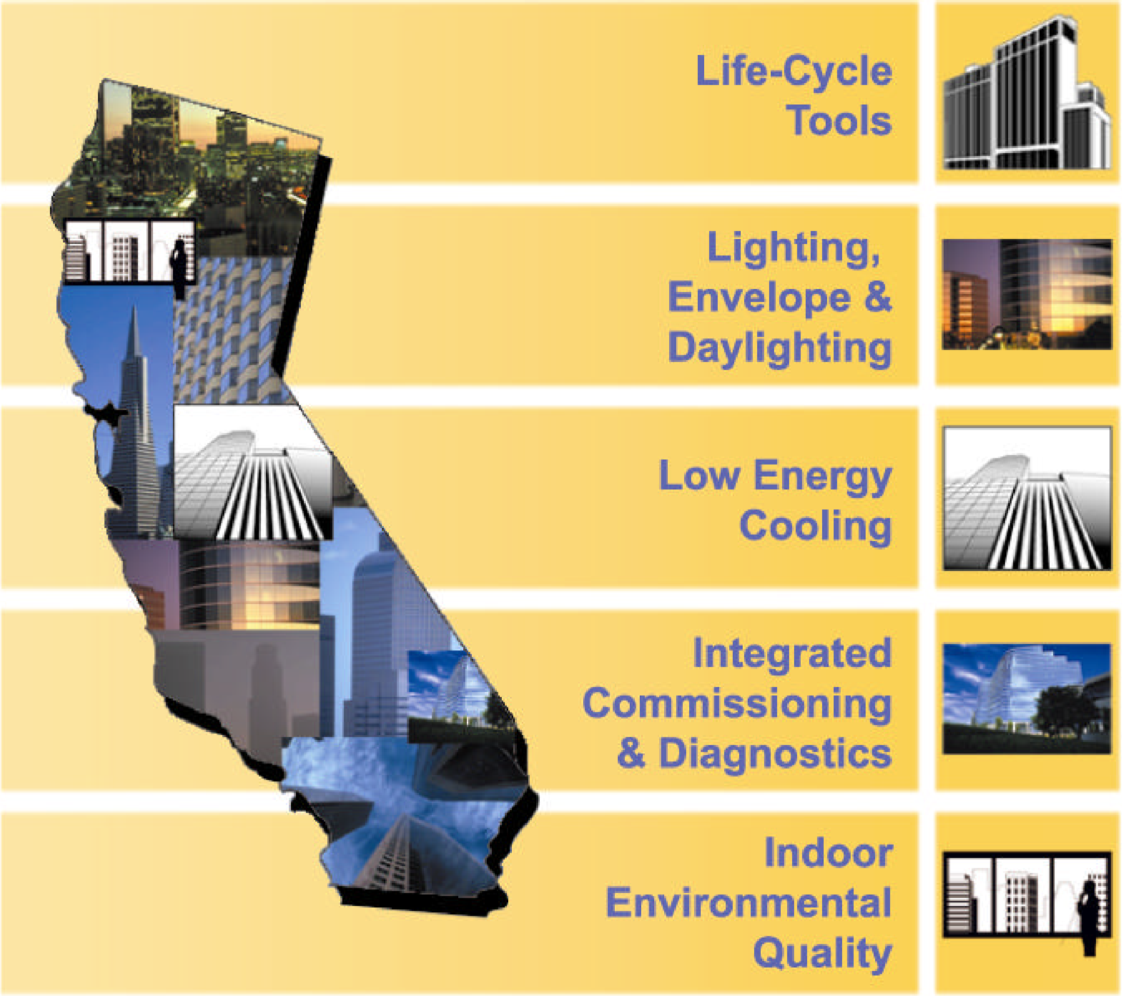
- Building life cycle perspective
- Process issues and Decision support tools - explicit and implicit energy decisions
- Information technology: data, tools
- Performance metrics and benchmarks
- Energy/Demand/$$ focus --> Green Buildings focus
- Sustainability, persistence over time

California Program Context

- PIER R&D <--> Deployment <--> Market Impacts
  - —CEC Building Standards
  - —Utility programs, CPUC programs
  - —State - Regional - National deployment programs
- “Summer of 01”- CPP and demand response
- Disaster/Hazard Response - Post 9/11 world
- Internet boom/bust and California economy

Program Organization

- **5 Interrelated Technical Elements**



Program Advisory Committee

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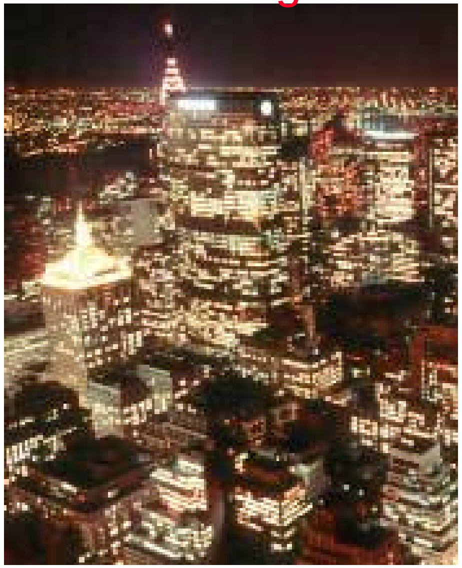
Program Impacts

NY Times HQ- El. 3

Benchmarking Your Building- El. 2

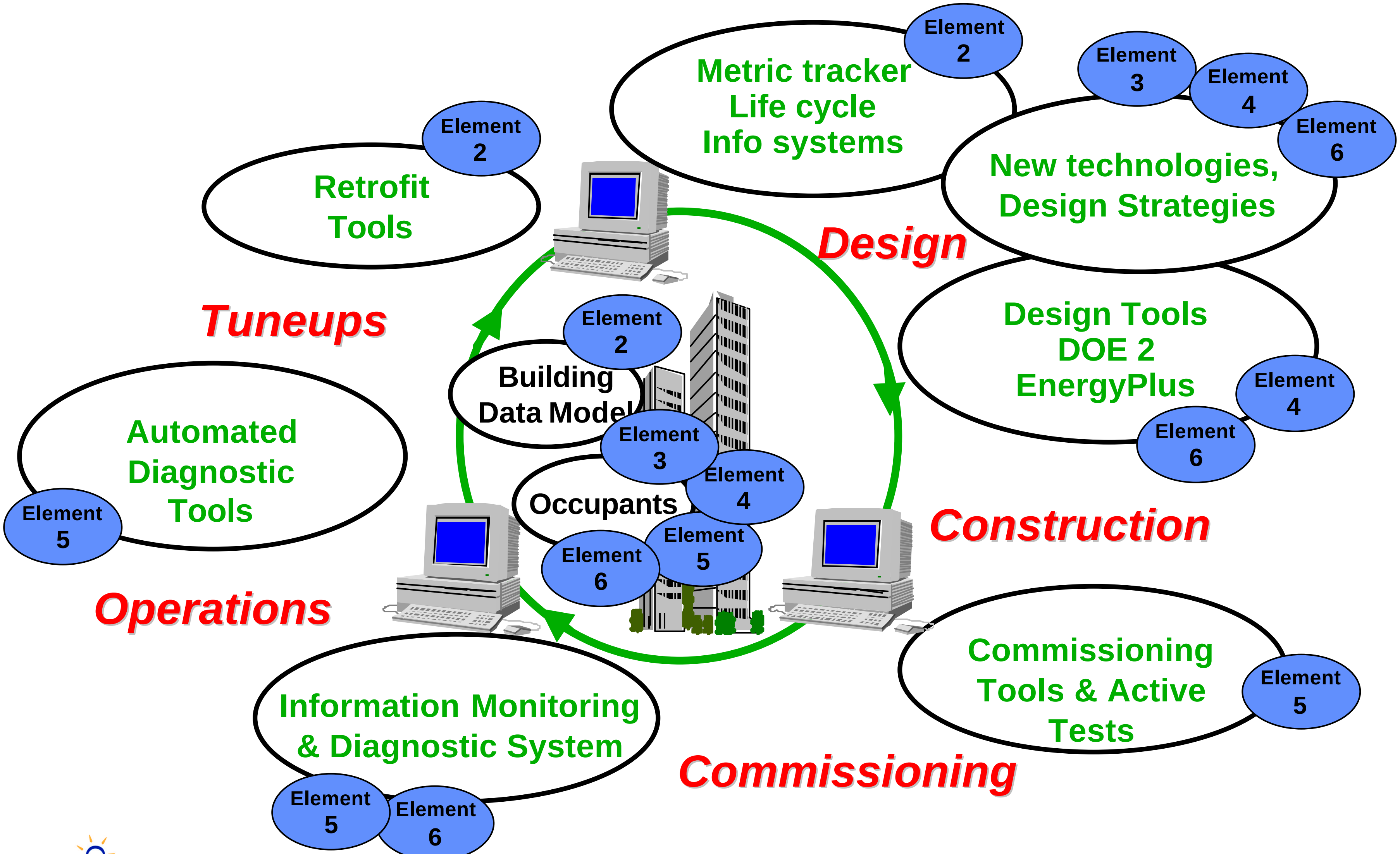


SF Fed building –El. 4

Portable Classrooms- El. 6

Oak Fed building-El. 5

HPCBS Seen in a Life-Cycle Performance Perspective



Status

- Completed Program Technical Work
  - 5 Elements, 14 Projects, 42 Tasks
  - Significant progress and accomplishments
- Guidance: sponsors, partners, TAG, PAC
- Output: 100+ reports, briefings, tools, conference presentations…
- Access, outreach:
  - CD, public web site
  - Papers, guides, codes, conferences, utilities, meetings...
- Follow-on market impacts
- Follow-on technical work

Today's Briefing

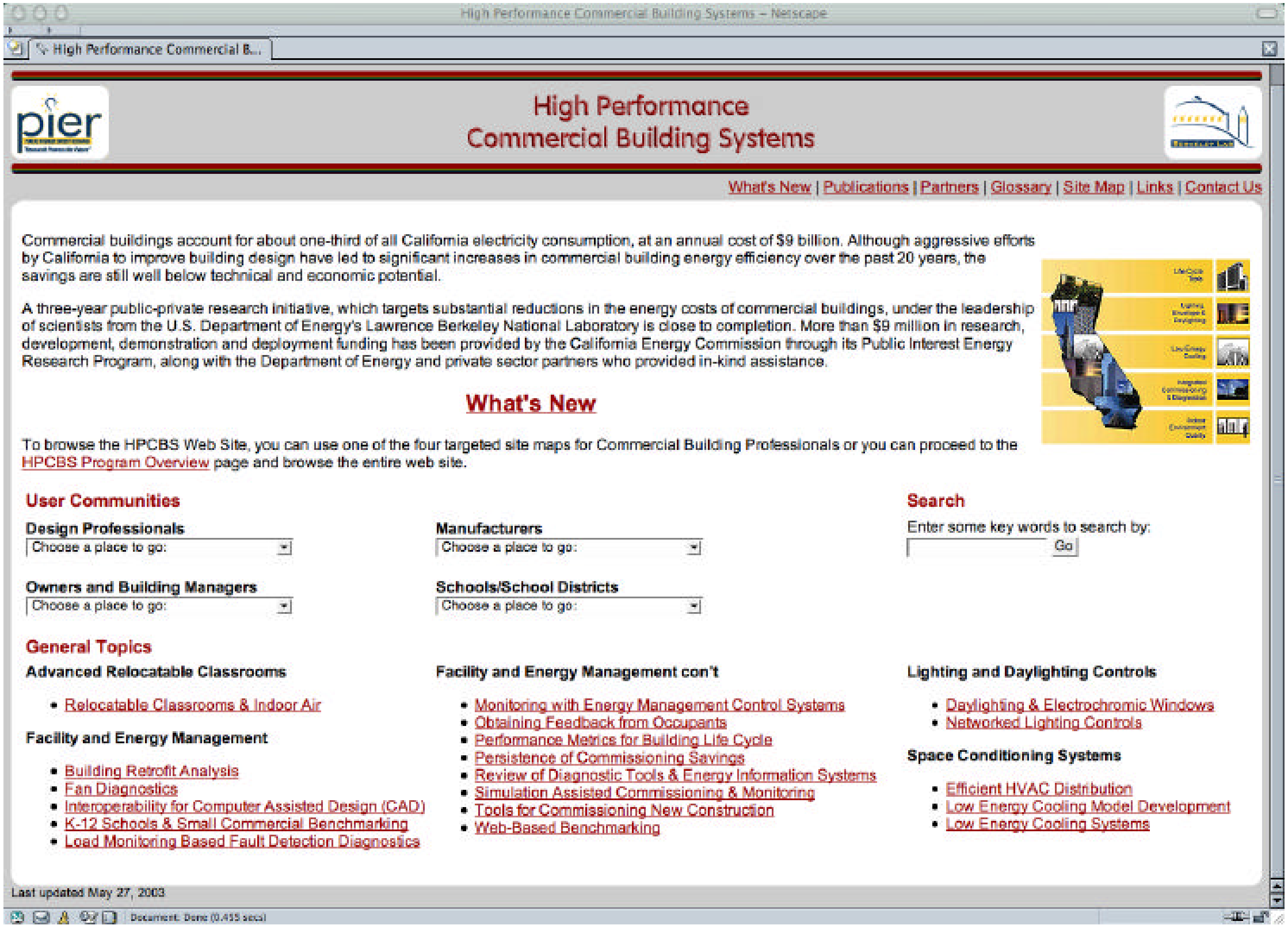
- Technical Progress
  - Captured in detail in final report, website
  - Navigating through $6M information resource
- Feedback on Accomplishments

1. More information on results
2. Your access to results
3. Market push/pull for greater market impacts
4. How to extend results
5. Missing pieces?

Market Connection Strategies

- Strategic Communications
  - —Articles in key industry publications
  - —Technical publications: researchers, advanced users
  - —Website: new public site
  - —Conferences
  - —Professional involvement: Title 24, ASHRAE, collaboratives (CHPS, CEE, CCC…)
- Specific partnerships, demonstrations
  - —Utility collaborations - CTAC, PEC, ETCC,…
  - —DOE, DOD, GSA, other private/public
  - —CA: CPUC, CHPS, DGS, UCOP,…

Program Website



High Performance Commercial Building Systems – Netscape

High Performance Commercial B...

High Performance
Commercial Building Systems

What's New | Publications | Partners | Glossary | Site Map | Links | Contact Us

Commercial buildings account for about one-third of all California electricity consumption, at an annual cost of $9 billion. Although aggressive efforts by California to improve building design have led to significant increases in commercial building energy efficiency over the past 20 years, the savings are still well below technical and economic potential.

A three-year public-private research initiative, which targets substantial reductions in the energy costs of commercial buildings, under the leadership of scientists from the U.S. Department of Energy's Lawrence Berkeley National Laboratory is close to completion. More than $9 million in research, development, demonstration and deployment funding has been provided by the California Energy Commission through its Public Interest Energy Research Program, along with the Department of Energy and private sector partners who provided in-kind assistance.

What's New

To browse the HPCBS Web Site, you can use one of the four targeted site maps for Commercial Building Professionals or you can proceed to the HPCBS Program Overview page and browse the entire web site.

User Communities

Design Professionals
Choose a place to go:

Manufacturers
Choose a place to go:

Owners and Building Managers
Choose a place to go:

Schools/School Districts
Choose a place to go:

Search

Enter some key words to search by:
Go

General Topics

Advanced Relocatable Classrooms

- Relocatable Classrooms & Indoor Air

Facility and Energy Management

- Building Retrofit Analysis
- Fan Diagnostics
- Interoperability for Computer Assisted Design (CAD)
- K-12 Schools & Small Commercial Benchmarking
- Load Monitoring Based Fault Detection Diagnostics

Facility and Energy Management con't

- Monitoring with Energy Management Control Systems
- Obtaining Feedback from Occupants
- Performance Metrics for Building Life Cycle
- Persistence of Commissioning Savings
- Review of Diagnostic Tools & Energy Information Systems
- Simulation Assisted Commissioning & Monitoring
- Tools for Commissioning New Construction
- Web-Based Benchmarking

Lighting and Daylighting Controls

- Daylighting & Electrochromic Windows
- Networked Lighting Controls

Space Conditioning Systems

- Efficient HVAC Distribution
- Low Energy Cooling Model Development
- Low Energy Cooling Systems

Last updated May 27, 2003

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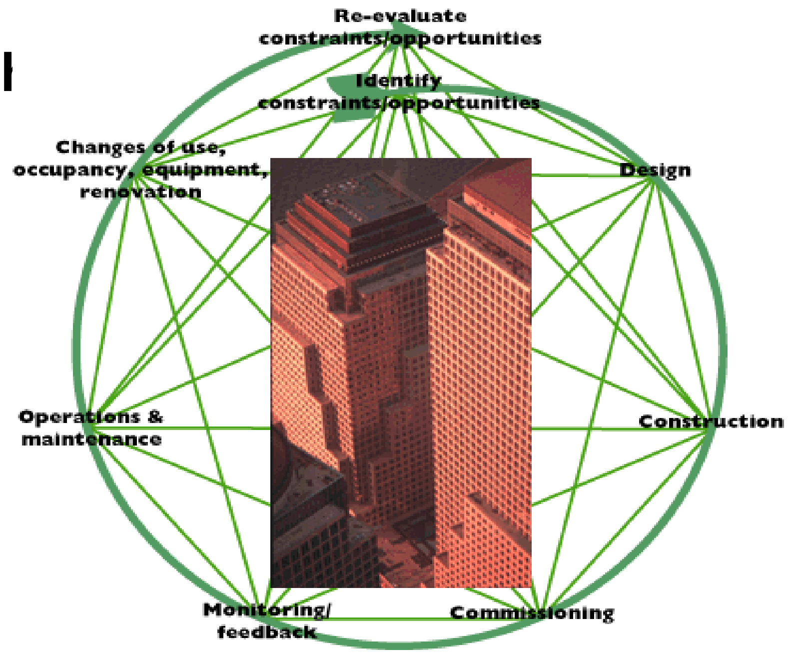
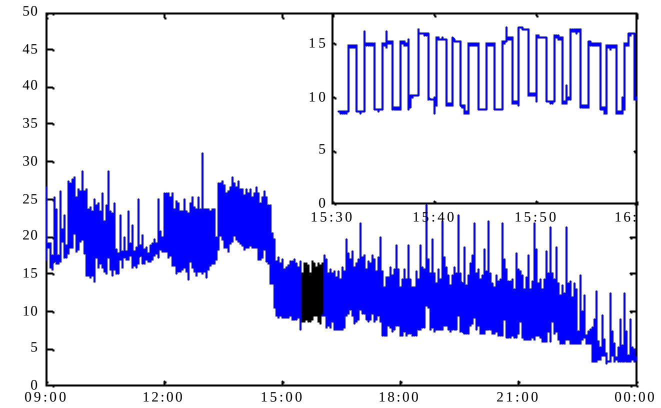
Element 2 Overview
Life-Cycle Tools

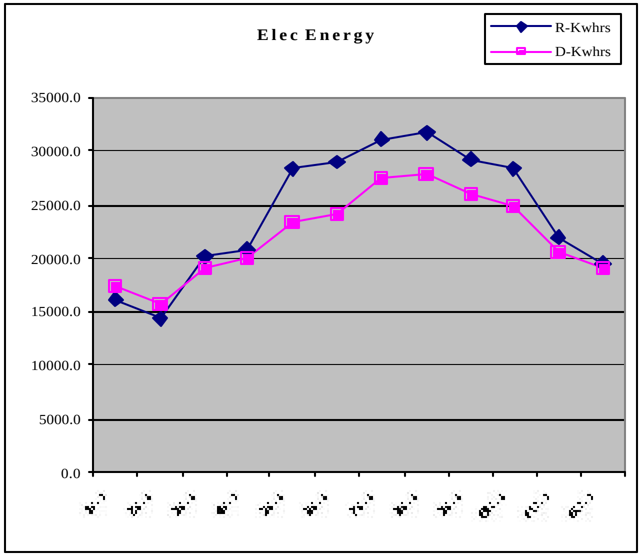
- Goal: **Develop integrated information management technologies to assist in improving commercial building performance**
- Problem: **Information fragmented & incomplete as it flows through building life cycle, current tools limited**
- Projects
  1. **Performance Metrics & Bench**
  2. **Retrofit Tools**
  3. **Interoperability**
- Team
  — **LBNL**
  — **MIT**
  — **Silicon Energy**
  — **EPA**
  — **GSA**



Element 2 Projects and Tasks

- Web-based Benchmarking Tool
- Performance Metrics Tracking Tool
- **Benchmarking with High-speed Electrical Monitoring**
- **Retrofit Energy Savings Estimation Method**
- Interoperability for HVAC Schema





Benchmarking Background

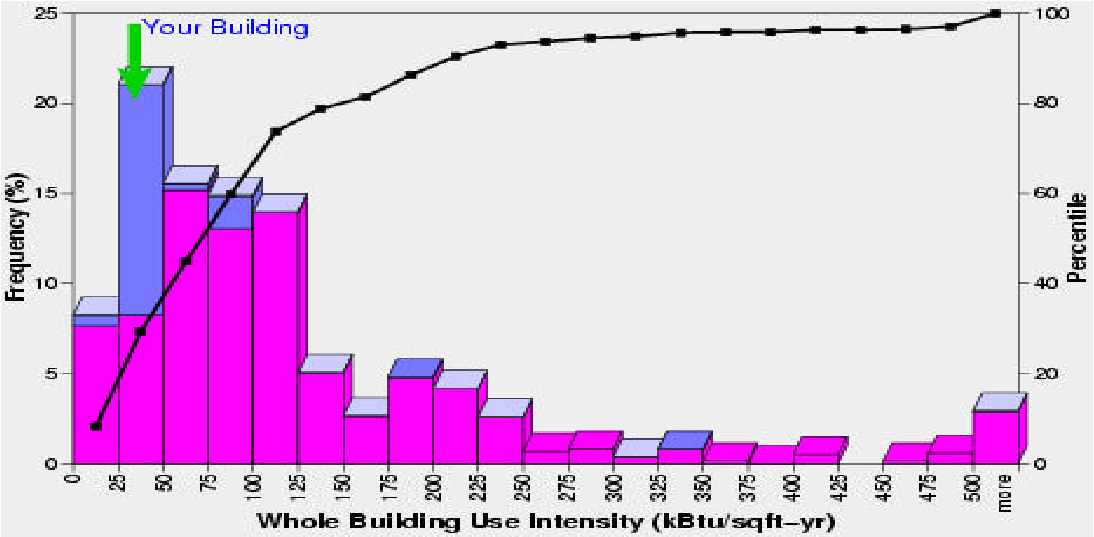
Benchmarking: **Process of comparison against standard or average**

- Why Benchmark?
  - **Determine how well a building is performing**
  - **Set targets for improved performance**
  - **Facilitate assessment of property value**
  - **Gain recognition**
- Why Use Regional Tools?
  - **Climate is main source of variation**
    - **HDD, CDD, humidity**
  - **Varying codes, incentives**
  - **Different fuels, prices**
  - **Most existing tools based on CBECS**
    - **Finest geographic resolution is Census Division**

Benchmarking and Cal-Arch

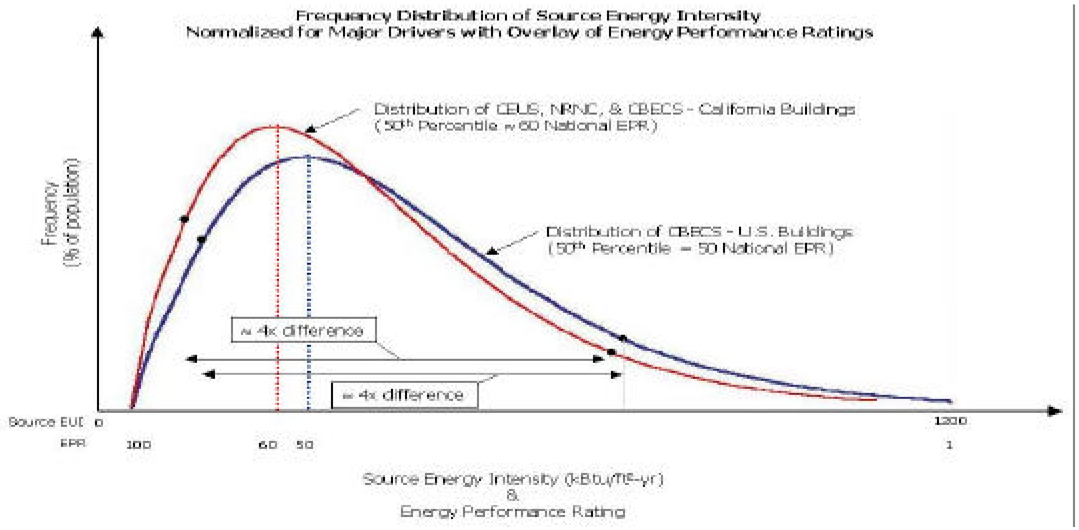
- Accomplishments
  - **Collaboration with EPA/CEC, industry, utilities, public workshops**
  - **ACEEE and ECEEE papers**
  - **Finalized online tool based on CEUS**

    poet.lbl.gov/cal-arch



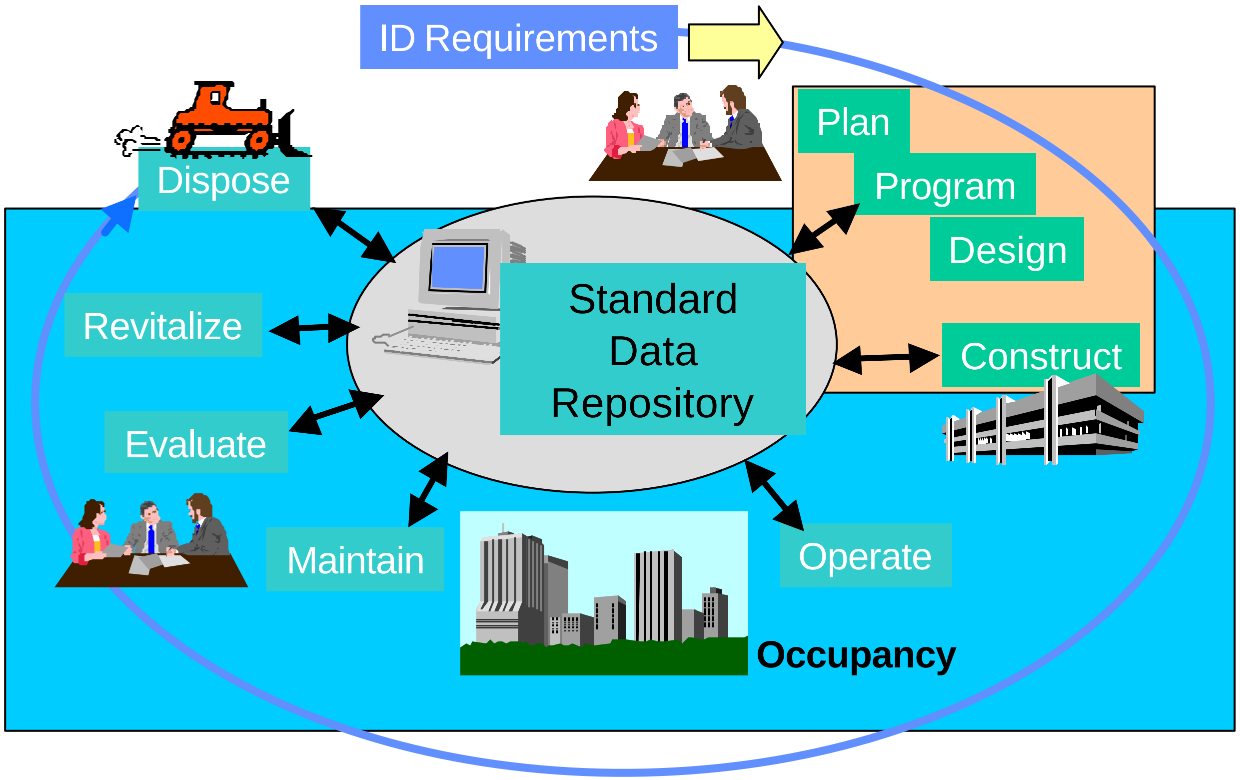
Benchmarking and Cal-Arch

- Next Phase
  - **Collaboration with California High Performance Schools Collaborative (CHPS)**
  - **Additional work with EIS companies**
  - **Future CEUS benchmarking**
  - **Collaboration on Energy Star**



Interoperability Background

- Data acquisition from upstream participants & tools
- Data archival for downstream participants & tools

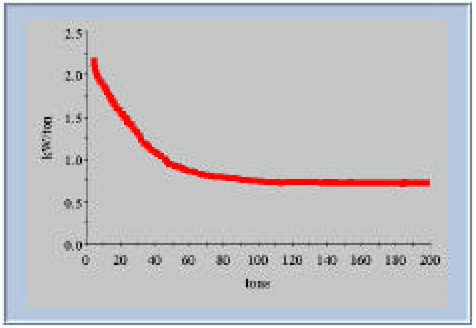


Interoperability Data Standards

- Object Data Model
  - — **Object-oriented model of the entire building**
    - **Elements (e.g., Walls) and Relationships (e.g., Walls->Space)**
  - — **Archive and exchange complete project data set**
  - — **Industry Foundation Classes (IFC)**
- Internet Data Exchange Models
  - — **Extensible models of data subsets**
    - **Product libraries (e.g., Chillers)**
  - — **Exchange of product and other data subsets to support transactions over the Internet**
    - **XML: aecXML, ifcXML**

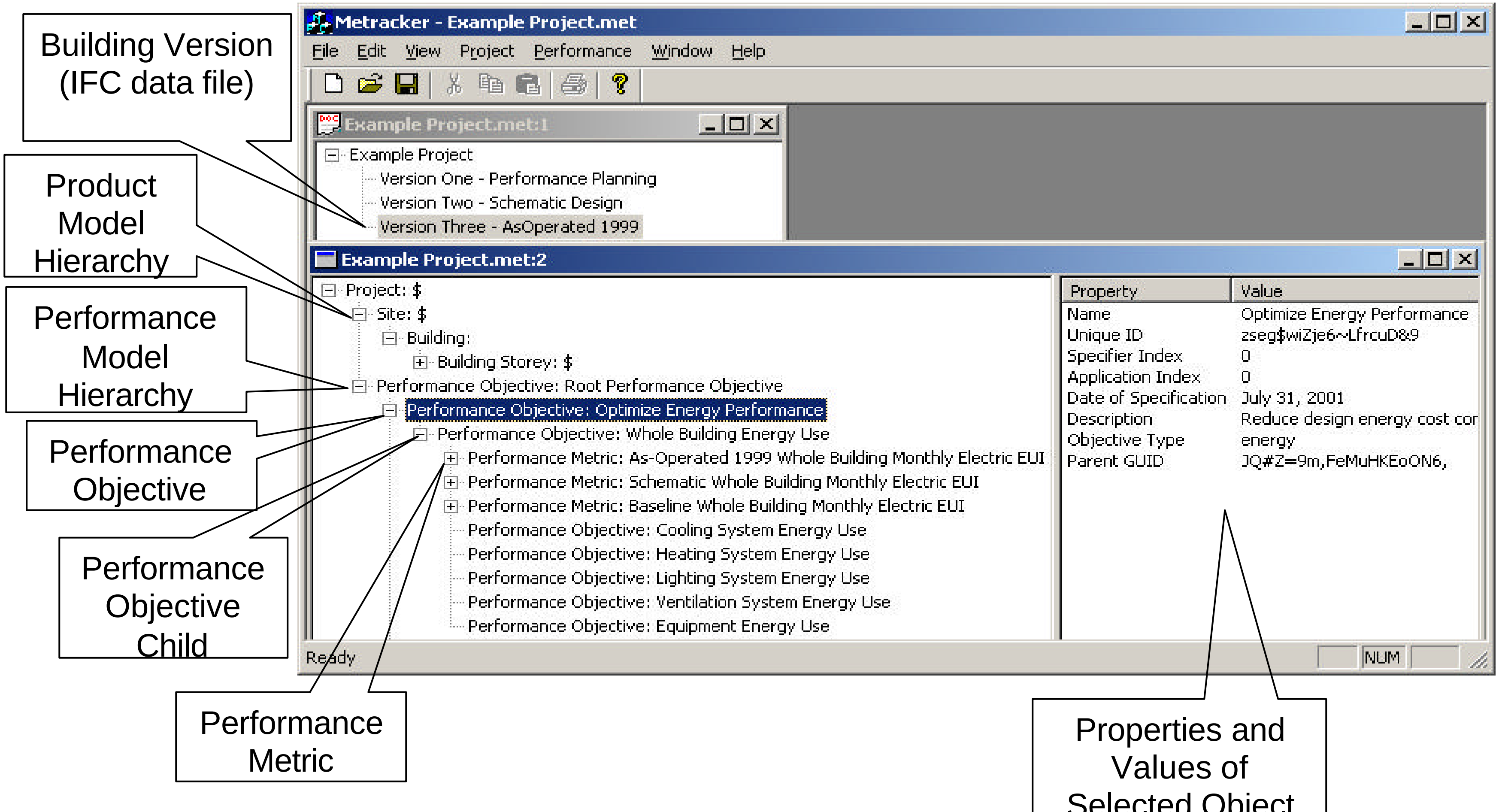
Data Archive for Downstream Applications

- Building and System Design Performance
  - **Expected Loads**
  - **Equipment Performance**
  - **Design Performance Benchmarks**
- Simulation Context Data
  - **Occupancy & Usage**
  - **Thermal Zoning**
  - **Building Systems Operation**
  - **Weather**



- Energy Use Intensity (kWh/ft^2/yr)
  - Heating EUI (kWh/ft^2/yr)
  - Cooling EUI (kWh/ft^2/yr)
    - Chiller (kW/ton)
    - Cooling Tower (kW/ton)
    - Cooling Load (tons)
  - Lighting EUI (kWh/ft^2/yr)
    - Office Lighting EUI (kWh/ft^2/yr)
      - Lighting System (W/ft^2)
      - Area (ft^2)
      - Operation (hours/yr)
    - Corridor Lighting EUI (kWh/ft^2/yr)
      - Lighting System (W/ft^2)
      - Area (ft^2)
      - Operation (hours/yr)
  - Ventilation EUI (kWh/ft^2/yr)
  - Equipment EUI (kWh/ft^2/yr)

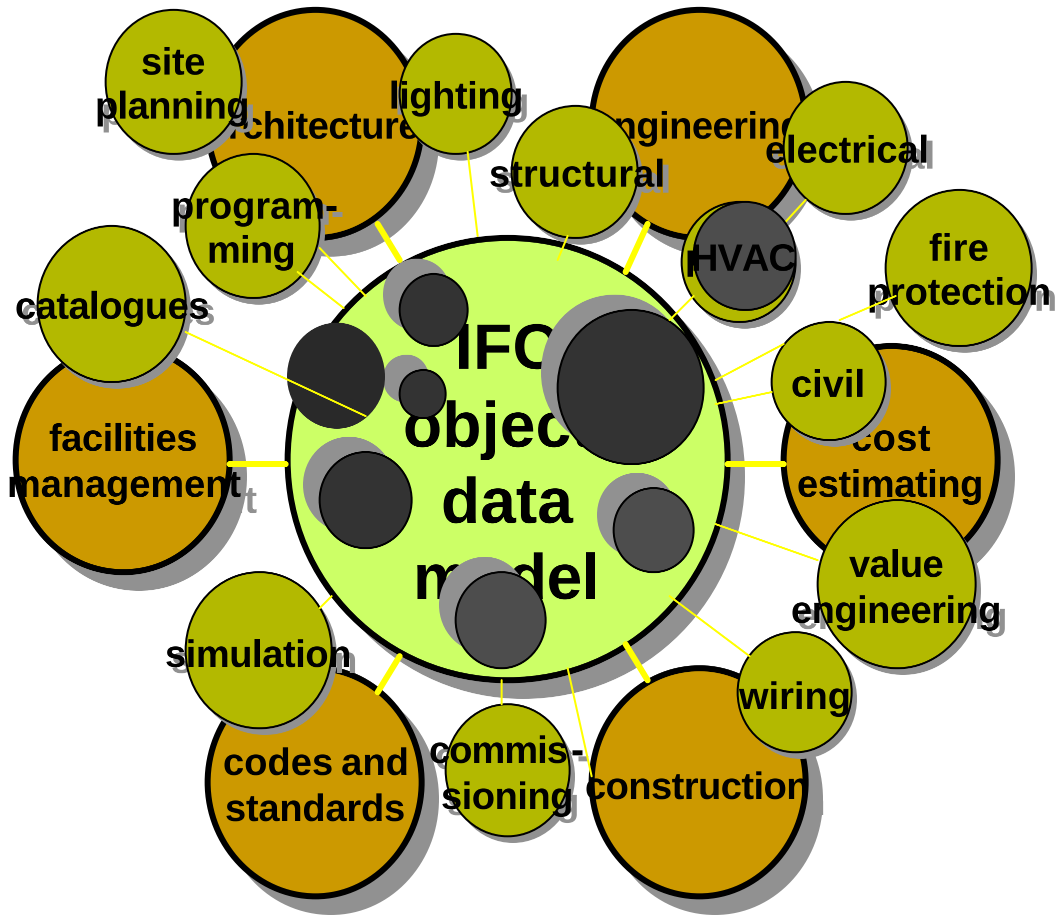
Metracker Software



- Accomplishments & Next Steps
  - **Prototype tool, produced papers & presentations**
  - **Collaboration with GSA and IFC Community**

Interoperability & Industry Foundation Classes

- Extended IFC schemata to support modeling HVAC systems
  - Design <-> Operations
  - Begin Implementation
  - Participants: **7 organizations in 5 countries**
    - Government**: Australia, EU, Finland and U.S., federal and state**
    - Private**: Finnish & French**



Interoperability & Industry Foundation Classes

- Accomplishments
  - **Supported use of simulation tools**
  - **Import information from upstream applications, e.g. CAD, in *.ifc or XML format (Building geometry, materials, etc.)**
  - **Export information to downstream applications in *.ifc or XML format**
- Next Steps
  - **Continued implementation with tools vendors, demonstrations and cooperation with IAI members**

Element 3 Overview
Lighting, Envelope & Daylighting

BERKELEY LAB

Goal: Develop an integrated building equipment communications network (IBECS) that will provide Internet-based control of lighting, daylighting and envelope systems

Problem: The high cost and complexity of integrated lighting and building envelope systems has limited market penetration

Projects

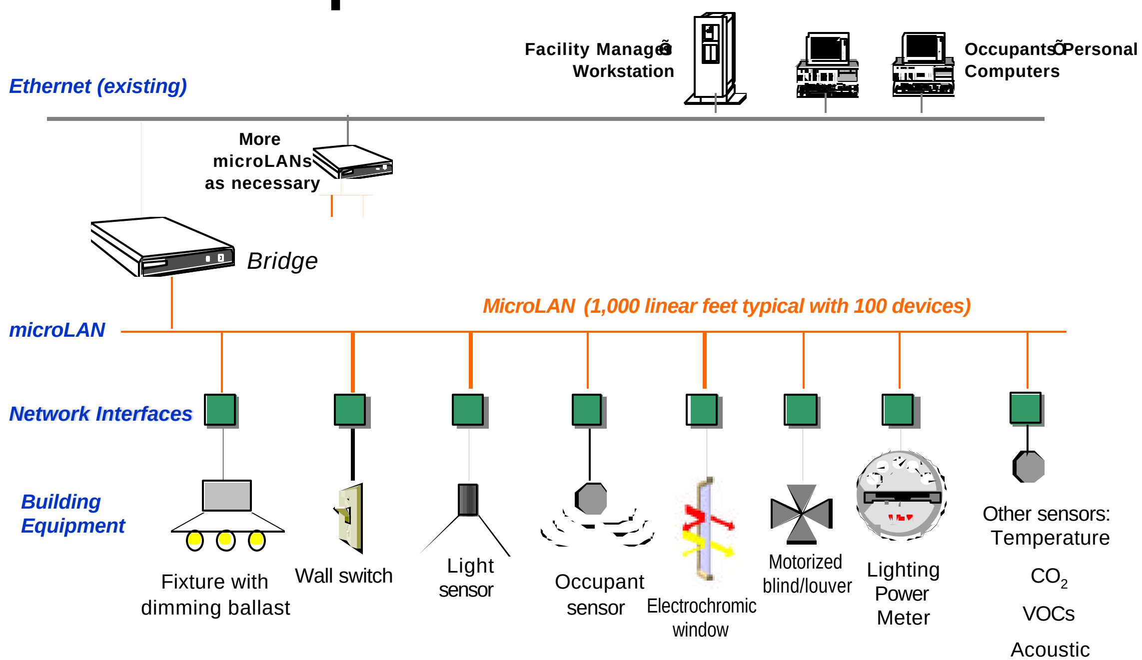
- **Lighting Controls**
- **Daylighting & Envelopes**
- **Network Operations**

Team

- **LBNL**
- **Vistron Corp.**

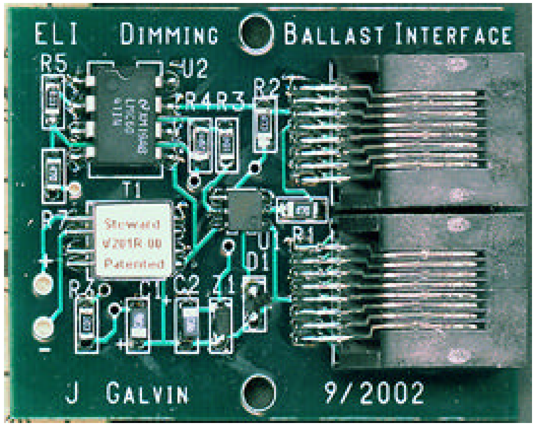
Element 3 Selected Major Tasks

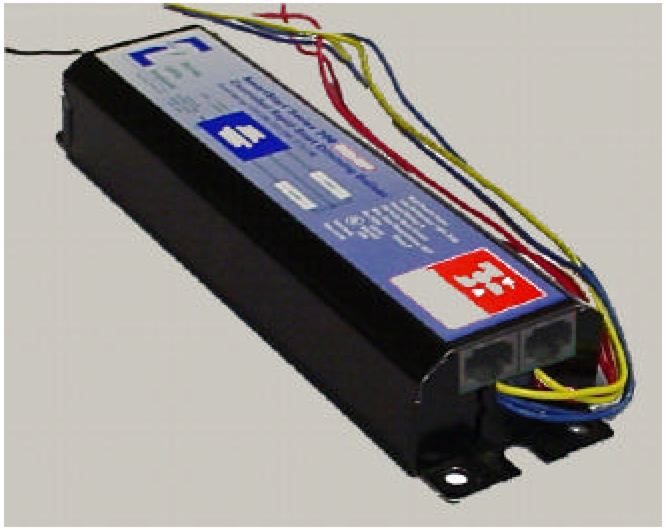
- Build and test key IBECS lighting components
- IBECS controlled motorized blinds and electrochromic windows
- Build demonstration network
- Communication protocol framework



Build and Test Key IBECS Components

- Accomplishments
  - —Successfully developed and tested IBECS ballast interface and addressable switch
  - —Developed prototype environmental sensor
  - —Demonstrated Powerline Carrier for switching lighting loads in existing buildings
- Next Phase
  - —Work with manufacturers to embed IBECS in control devices
  - —Demonstrate advantages of digital control to early adopters



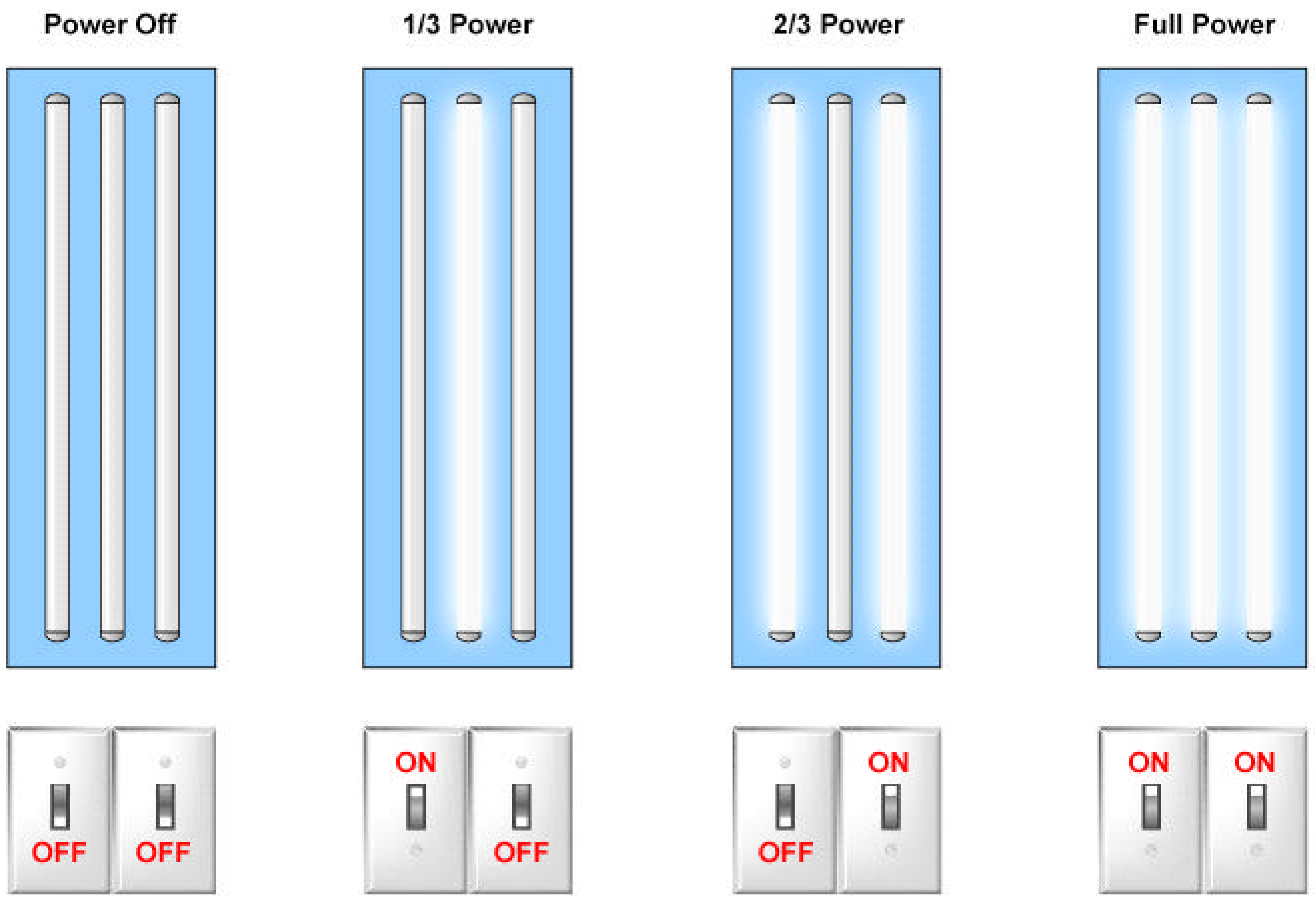


Addressable Wall Switch

Title 24 Wall Switch

- **Produced IBECS-addressable switch "proof-of-concept"**
- **Demonstrated off-the-shelf solution for controlling lighting relays *in existing CA buildings* using Power Line Carrier (PLC)**
- **Solution addresses the huge load represented by all the bi-level switches installed in California commercial buildings since 1982**

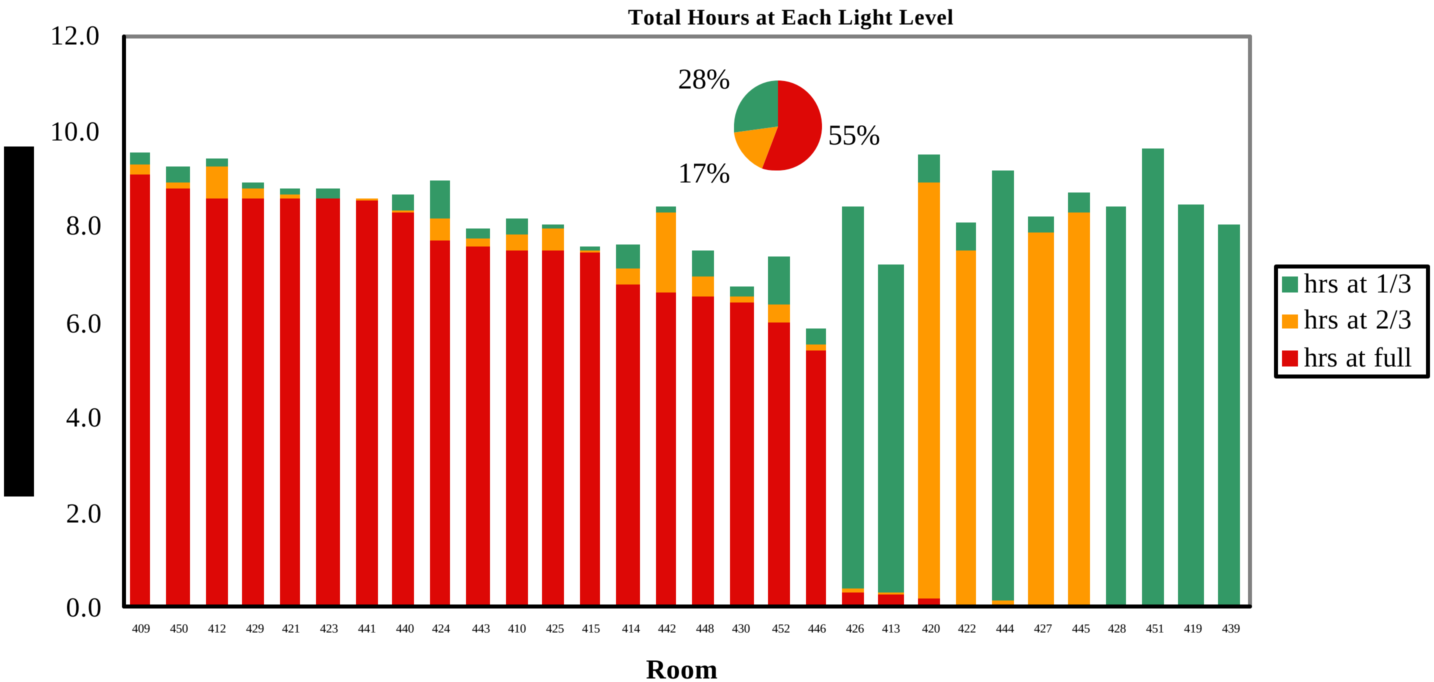
Bi-Level Switching: How It Works



Bi-Level Switching: How It Works
One switch operates the outer two lamps while the other operates the inside lamp

Bi-Level Switching *Works!*

Average Number of Hours Per Day At Three Different Light Levels

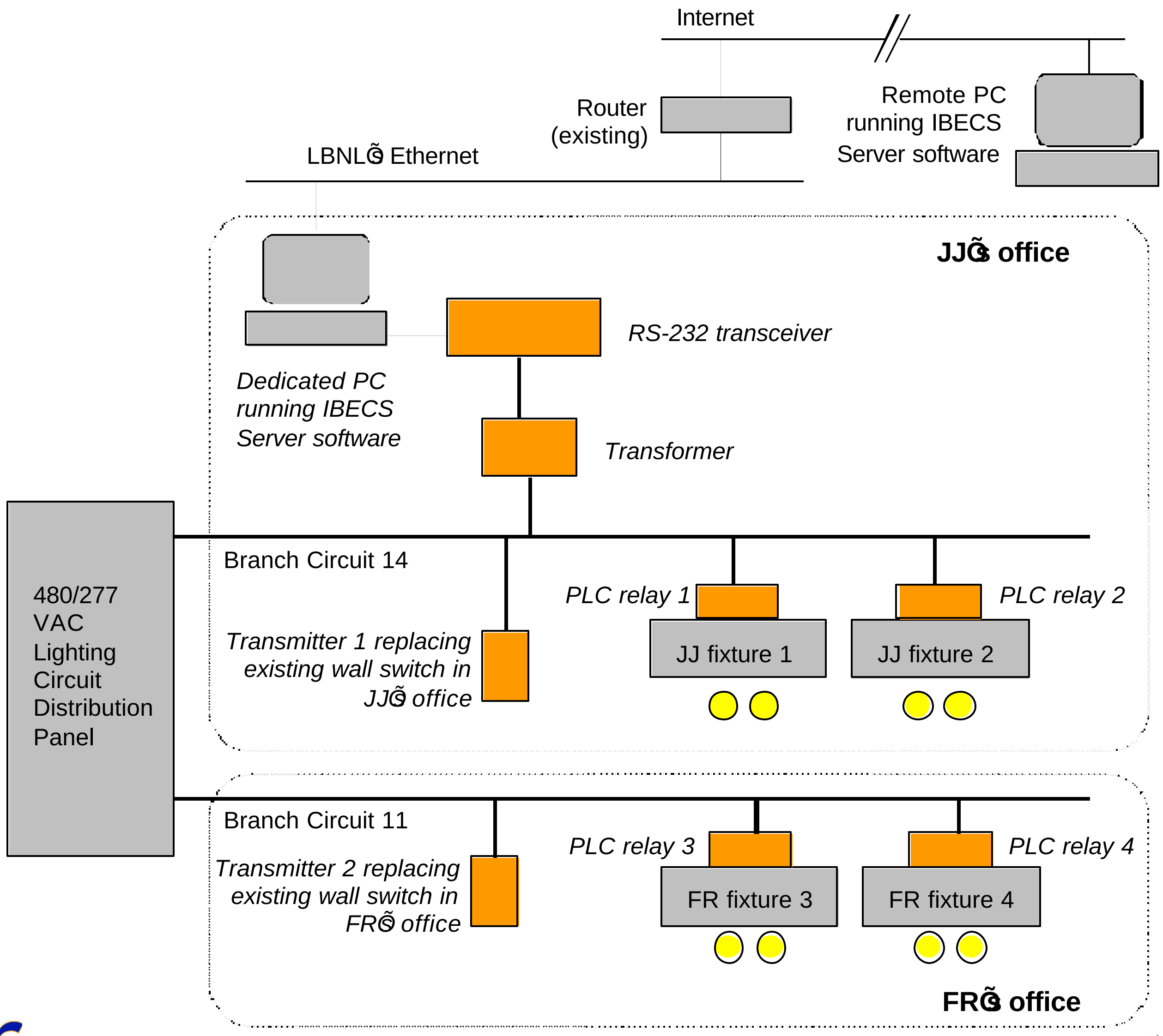


30 perimeter offices over 7 months

- **Occupants use bi-level switches *effectively***
- **Reduced lighting energy by 20-25%**

Imagine the possibilities for remote control

Demonstrating Powerline Carrier Switching System



Lessons Learned from the PLC Demonstration

- Today's powerline carrier is much improved over yesterday's
  - —PLC is one appropriate method to enable remote control of most bi-level lighting loads in existing CA buildings
- Other methods are also appropriate, including RF and improved PLC methods
- We should use existing wiring as the basis for communicating with lighting loads ***in existing buildings:***
  - —*Load shed* ballasts
  - —Intelligent relays (leverage CA's historic investment in bi-level switching)

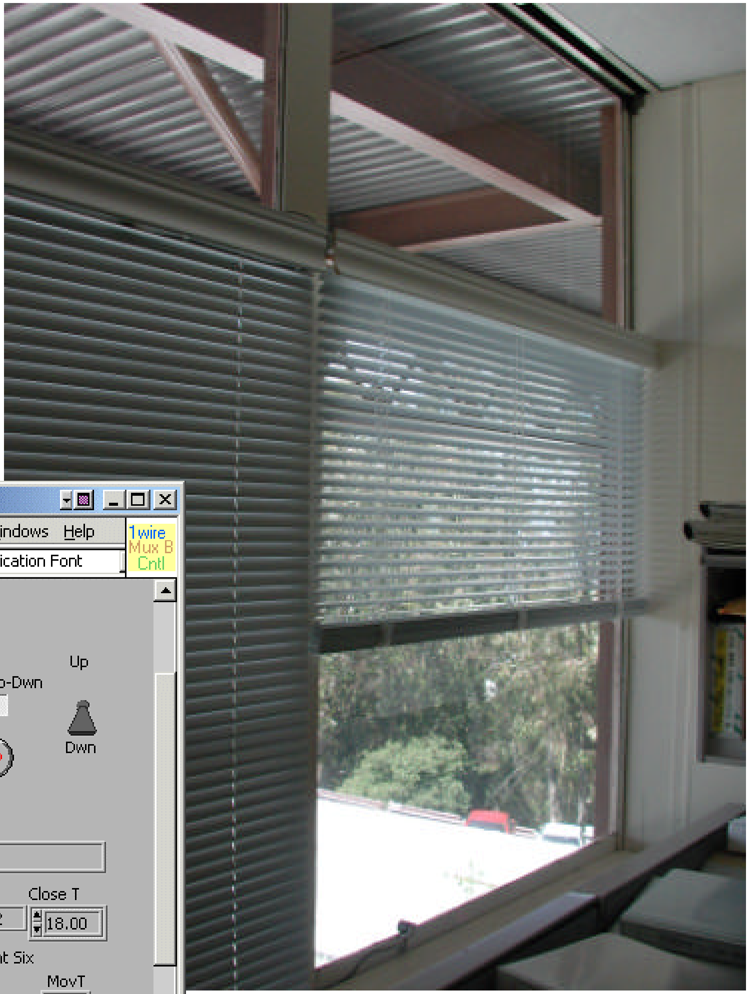
IBECS Controlled Motorized Blinds and Electrochromic Window

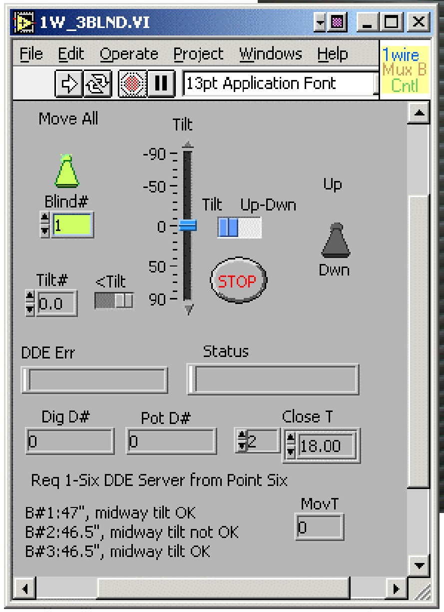
Accomplishments

Demonstrated feasibility of IBECS for controlling motorized blinds and EC windows

Engaged shade device manufacturers about adopting IBECS

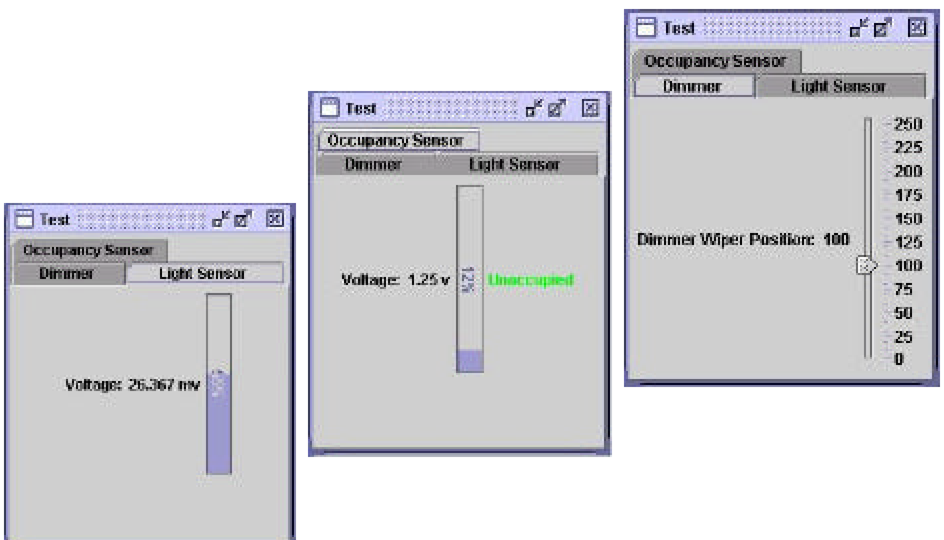
Initiated integrated shade and dimmable lighting demo at NY Times mockup





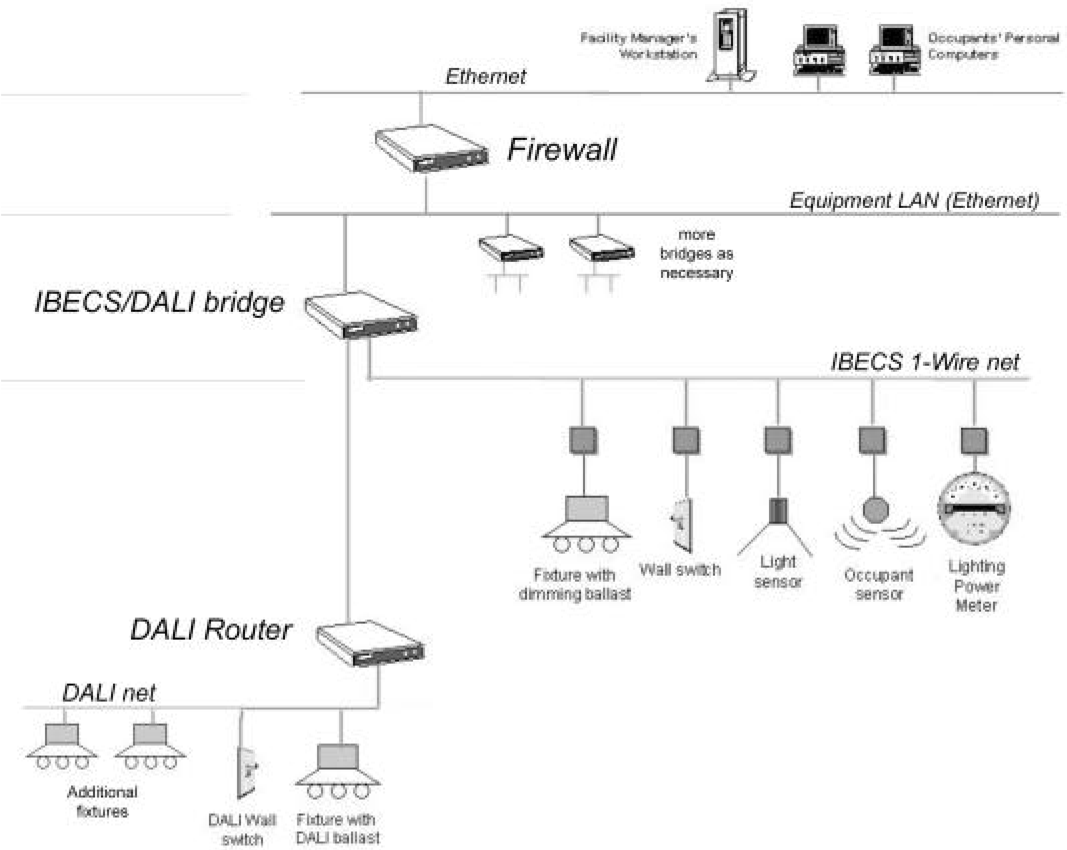
Build IBECS Demonstration Network

- **Accomplishments**
  - Installed demonstration network of IBECS prototypes at LBNL
  - Produced rudimentary software for reading and controlling attached devices
  - Improved sensors so external power unnecessary



Framework for Unifying Digital Communication Protocols

- **Accomplishments**
  - **With NIST, developed framework that unifies BACnet, DALI and IBECS**
  - **IEEE paper: "Standardizing Communications Between Lighting Control Devices"**
- **Next Phase**
  - **Work with manufacturers of DALI products to combine IBECS sensing with DALInet control of digital ballasts**



Lessons Learned

- Importance of engaging manufacturers
  - Embedding technology into existing products lowers cost of deployment
- Need to work with and complement DALI
  - Only digital protocol accepted by major ballast companies
  - Physical compatibility (two wires, not four)
  - Commissioning is barrier to all digital controls
- Need to integrate with BACnet
- Software development is expensive
- Need cadre of software developers to write cool software
  - Open standards

Sitting on a Gold Mine

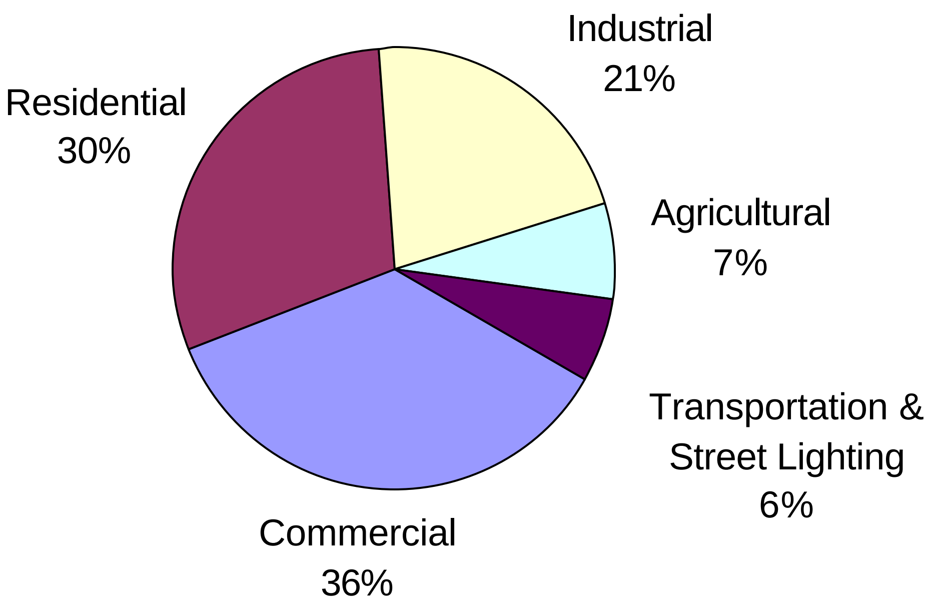
- Title 24's "bi-level" switching requirements in place in CA commercial buildings since 1982
- The lighting energy consumed in CA offices, retail, foodstores and miscellaneous is 15 BkWh/yr
  - —Equivalent to 4.7 Gigawatts
- There is 1 - 1.5 Gigawatts of lighting load that could be shed without affecting productivity or comfort
  - —Economic value: *$1 billion!*
- We propose using intelligent relays and PLC-type control to mine this power source in CA commercial buildings

Element 4 Overview – Low Energy Cooling

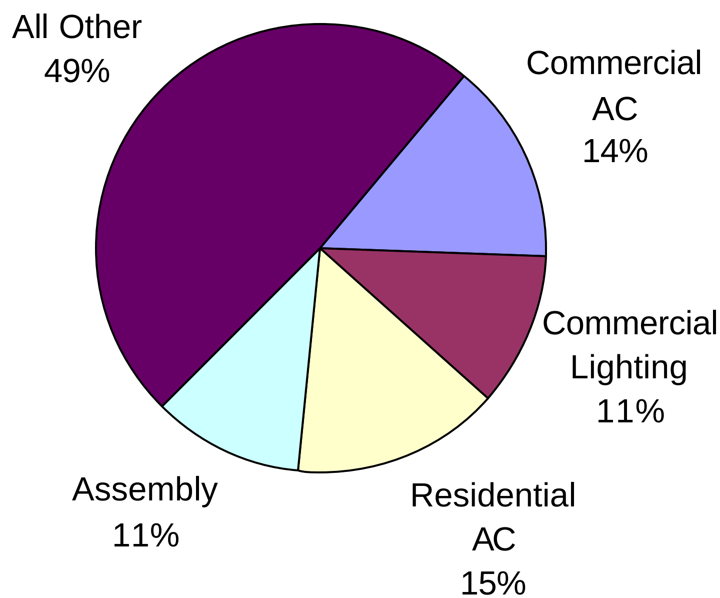
- **Goal**: **Reduce cooling energy use and peak demand**
- **Problem:** Complexity and risk associated with Low Energy Cooling strategies; lack of tools, code acceptance
- **Projects**
  1. **Appraisal of System Configurations**
  2. **Model Development**
  3. **Efficient Thermal Distribution Systems - Ducts**
- **Team:**
  — LBNL
  — UC San Diego
  — Arup
  — Flack+Kurtz

Appraisal of System Configurations: Problem Statement

Electricity Use



Peak Demand



Conventional cooling systems are energy intensive and contribute to peak demand, yet do not exploit California climate conditions

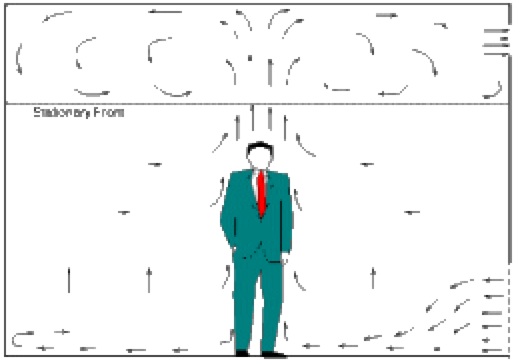
Objective: identify combinations of low energy cooling strategies and technologies that have significant potential for California

Appraisal of System Configurations: Approach

BERKELEY LAB

System Design Strategies

- Eliminate or reduce chiller use
  - — **evaporative cooling, natural ventilation …**
- Cool spaces more effectively
  - — **displacement ventilation, radiant cooling …**
- Shift/smooth peak demand with thermal mass
  - — **exposed slabs, raised floors**
- Improve distribution systems
  - — **hydronic systems inherently more efficient**

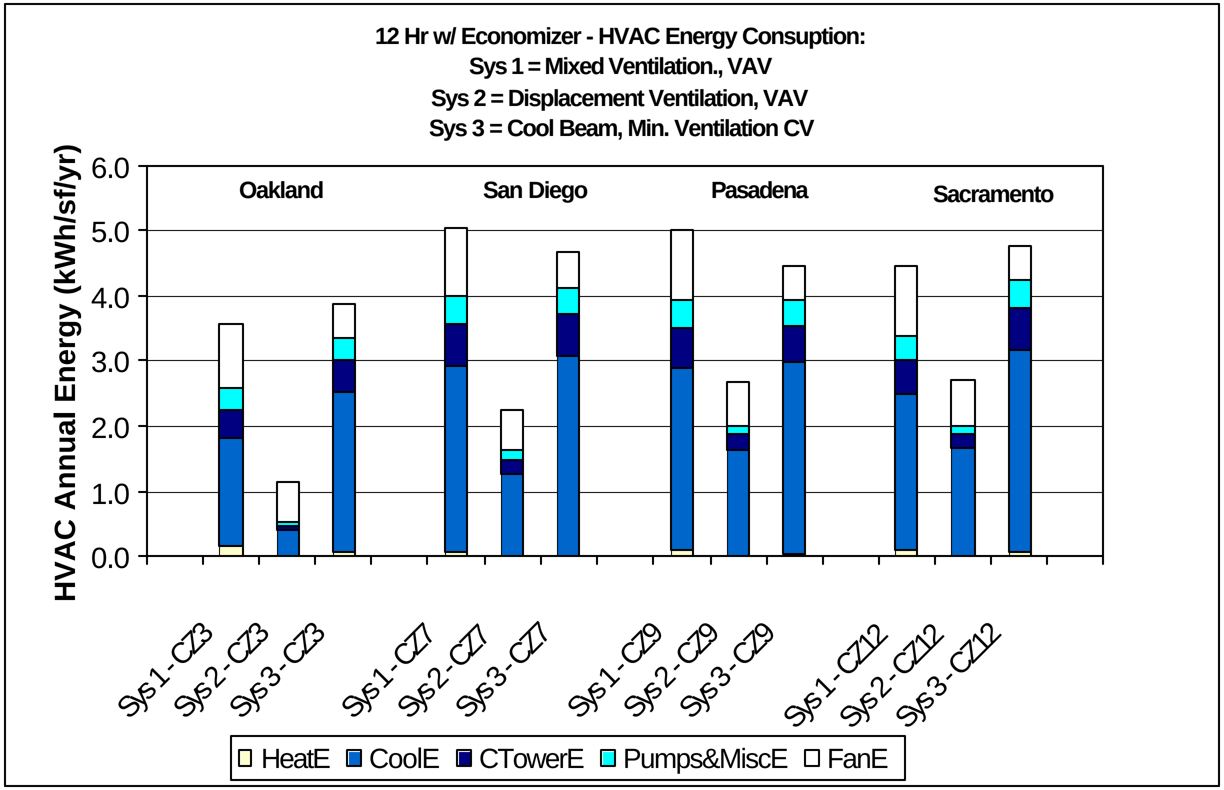


Use simulation to assess the potential of different strategies in different climates and building types

Appraisal of System Configurations: Results

DOE-2 Results

- **Displacement ventilation:** major savings (30-60%), more with indirect evaporation, especially in hotter climates
- **Chilled ceilings** reduce peak demand by reducing fan power, no energy savings without water-side free cooling



EnergyPlus Results

- **Displacement ventilation results less dramatic but still show significant savings**

Model Development: Problem

- Cooling technologies with promise for California can not be modeled adequately in DOE-2 and other energy simulation programs:
  - —Displacement ventilation
  - —Natural ventilation
  - —Radiant slab cooling
- EnergyPlus is the most suitable platform

Objective: develop new models for low energy cooling simulation and implement in EnergyPlus

Model Development: Approach

Develop new room models that provide a first order treatment of the unmixed airflows that minimize cooling energy use:

- Displacement ventilation:
  - — 2 layer model predicts:
    - temperature in occupied zone
    - return temperature
    - boundary height
- Natural ventilation:
  - — cross flow: jet and recirculation regions
  - — internal stack: stratification - 2 layer model

Implement in EnergyPlus and document for possible implementation in other programs

Model Development: Implementation

Flow model is selected each time-step…

Mixed	Stratified	Cross flow
	Displacement vent. model	Recirculation model
Single node model	DV two node model	CV two node model

….and is executed by EnergyPlus

Model Development: Outcomes

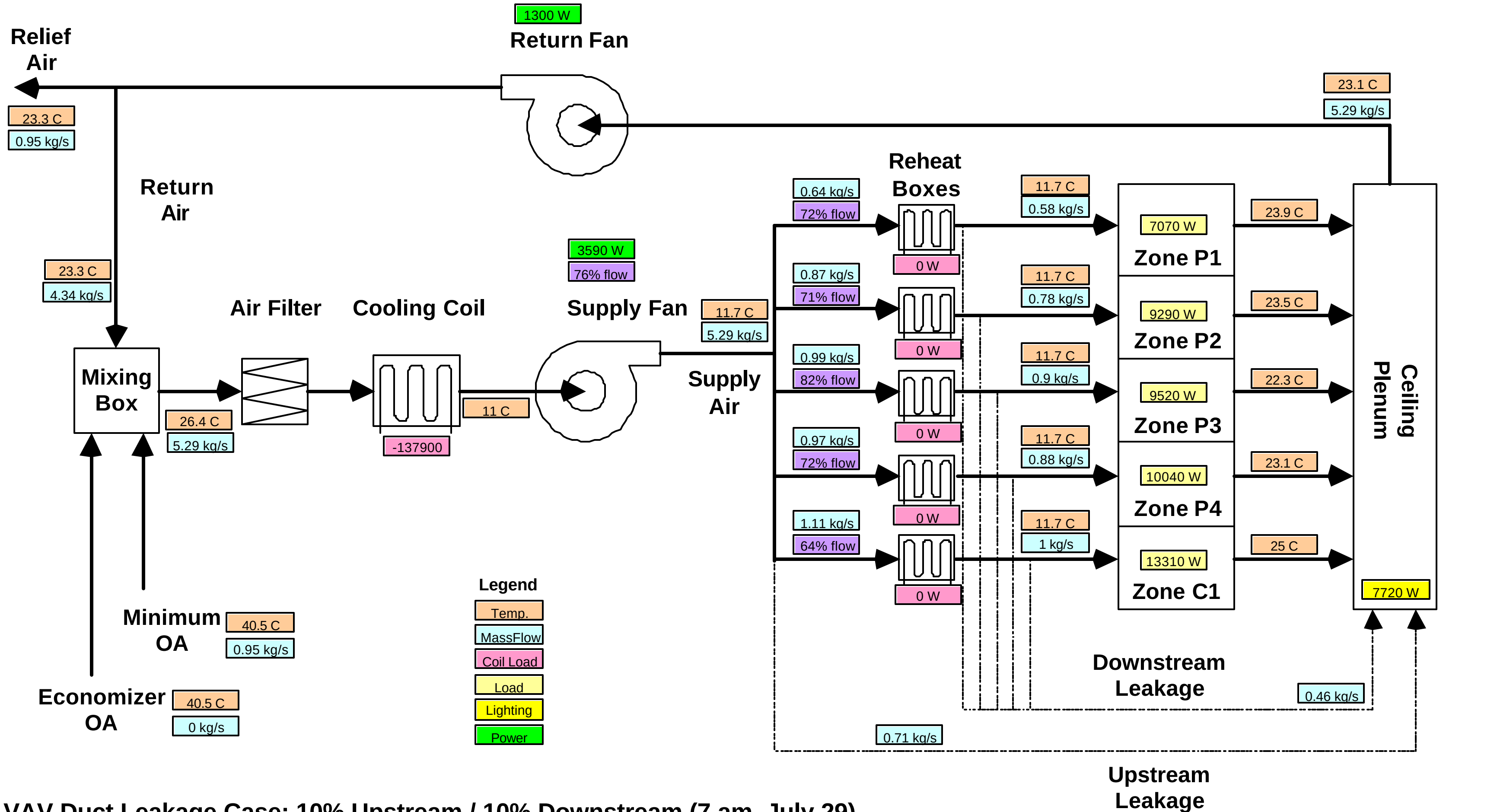
EnergyPlus models used in

- **design assistance:**
  - — **new S.F. Federal Office Building:** natural ventilation, no mechanical cooling
  - — **museum for San Diego**
  - — **community college in San Jose**

- **system appraisal:**

  displacement ventilation model predicts operating limits and provides guidance for designers

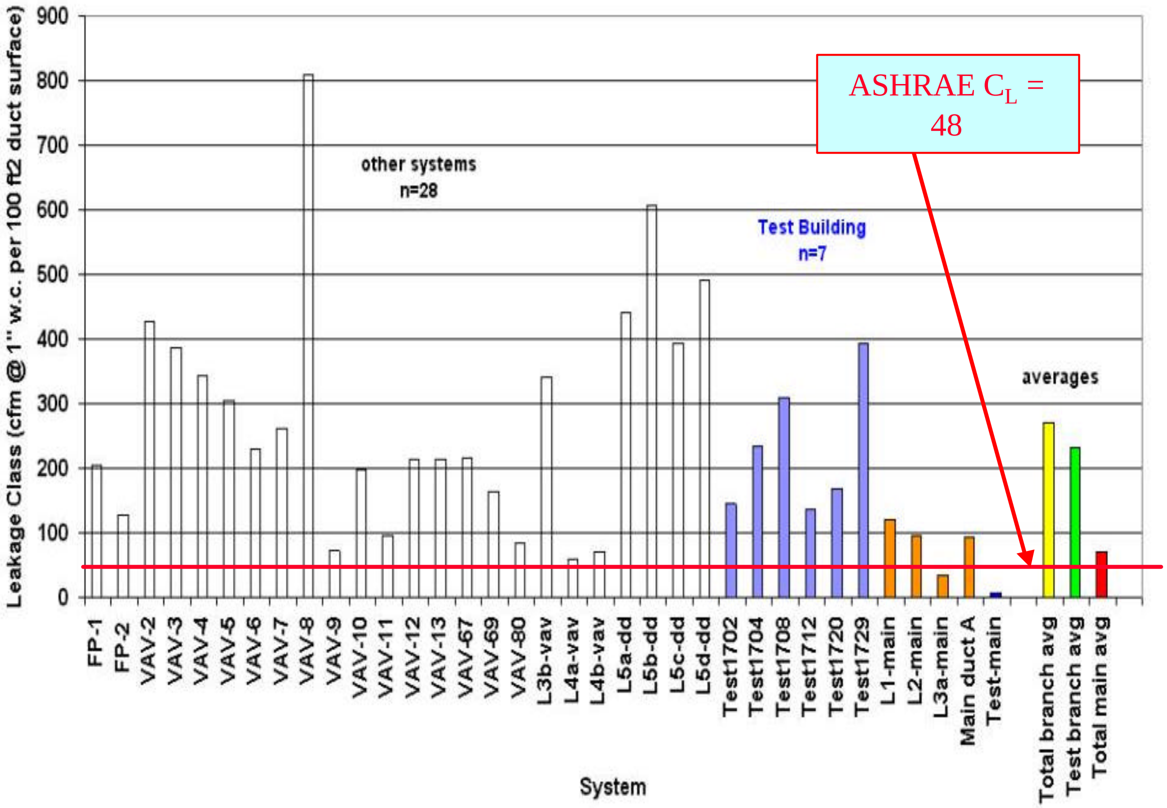
Efficient Distribution Systems



VAV Duct Leakage Case: 10% Upstream / 10% Downstream (7 am, July 29)

Leaky Ducts

- **Background**
  - **No T24 incentive for energy-efficient ducts in large commercial buildings**
  - **Potential leakage-related savings in CA: 560 to 1,100 GWh/yr fan energy + 100 to 200 MW peak demand**
- **Objectives**
  - **Develop simulation tools & metrics to support performance-based T24 compliance path**

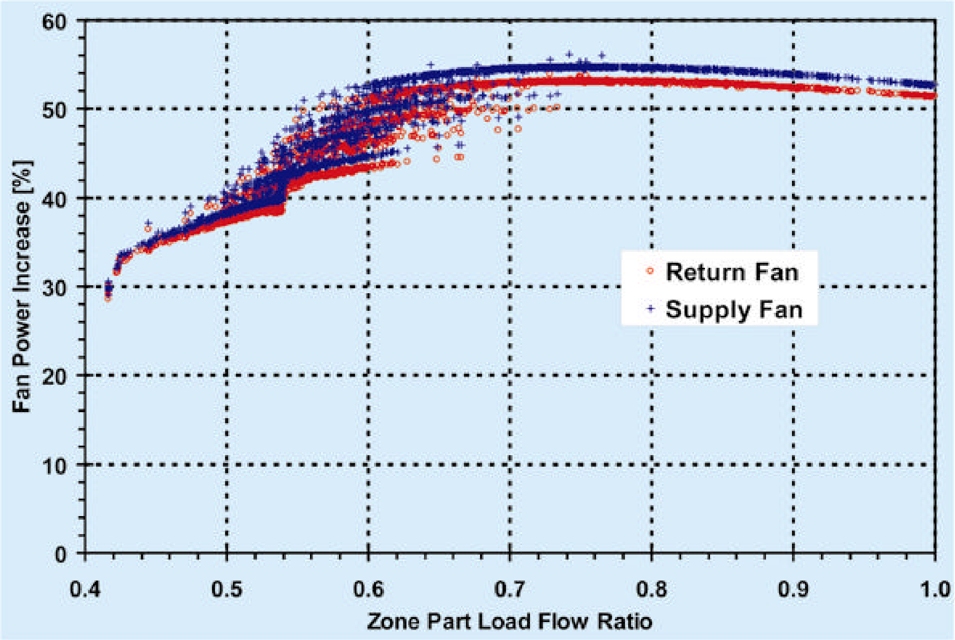


Addressing the Problem

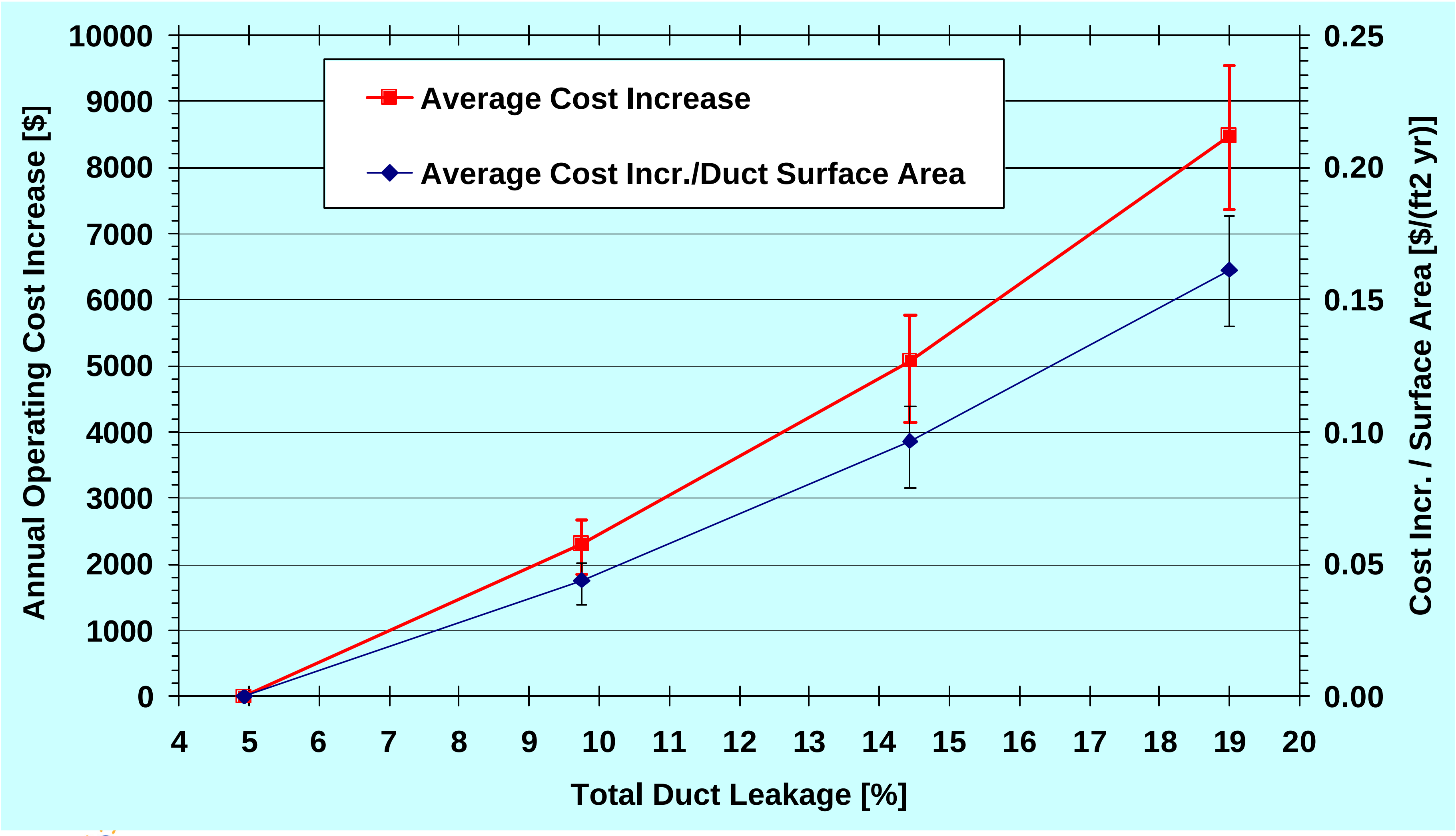
- **Provide Foundation for Compliance Tools**
  - **Review duct modeling literature, identify short- & long-term simulation approaches**
- **Extend Understanding of Leakage Impacts**
  - **Use short-term approach to assess energy impact variability for 54 combinations of duct leakage, building vintage, & climate**
- **Identify Efficient HVAC Systems**
  - **Propose new T24 metric to compare systems (e.g., air vs. hydronic, distributed vs. central)**

Project Results

- Modeling Approaches
  - — Future: EnergyPlus;
    Now: DOE-2/TRNSYS hybrid
  - — Documented duct component models (TRNSYS)
- Large Commercial Building Impacts
  - — Prescribe single duct leakage threshold in T24, independent of building vintage & location
  - — Sealing duct leaks is cost-effective, at least for VAV systems with 10% or more leakage
- Transport Efficiency
  - — New reporting requirement for 2005 T24 ACM

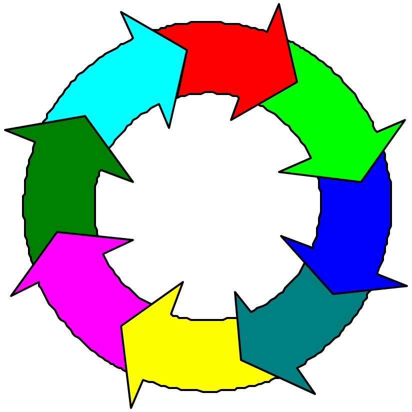


Sealing Ducts Makes Sense



Further Work – Industry Needs

- **Stock Characterization**
  & Energy Savings Potential
- **Design & Construction**
- **Codes & Standards**
- **O&M, Diagnostics, Commissioning**



Element 5 Overview Integrated Commissioning & Diagnostics

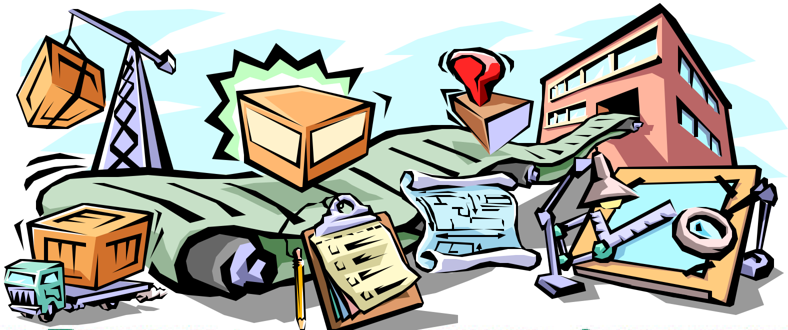
- **Goals**
  - Commissioning of new commercial buildings as standard practice
  - Retro-commissioning and continuous monitoring of existing building systems widely practiced
- **Problem:** Buildings do not perform as designed or expected after handoff to building owners
- **Team**
  - Texas A&M
  - LBNL
  - PECI
  - MIT
  - UC Berkeley
  - University of Nebraska
  - Arup
  - Flack + Kurtz
  - Silicon Energy

Problems and Opportunities

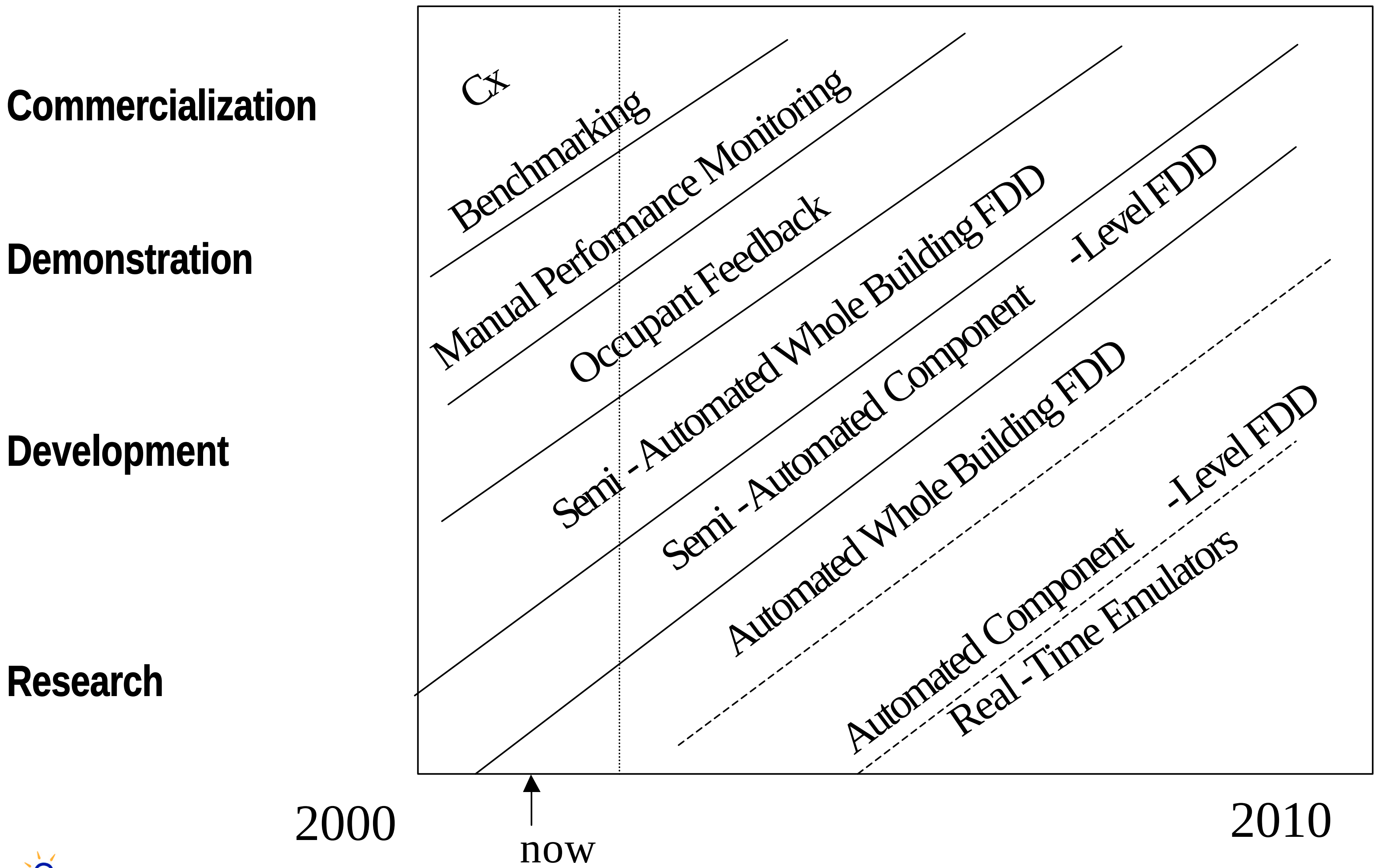
Design, construction and operations process is broken

- **Comfort and IAQ problems when new, increasing complexity**
- **Comfort and IAQ problems increase with age**
- **Efficiency decreases with age**

- Opportunities for early adopters
  - **Commission new buildings: eliminate most problems**
  - **Supplement operation with on-going and retro-commissioning**
    - **Improved comfort**
    - **Energy cost cut by 10 – 20%**



Layers to be Added to Simulation for Commissioning



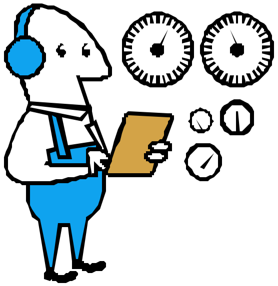
Integrated Commissioning & Diagnostics Projects

New Buildings

- Controls System Design and Functional Test Guide

Existing Buildings

- Fault Detection Procedures and Energy Information Systems
- **Guide to EMCS Use for Monitoring**
- **High-Information-Content Electrical Load Monitoring**
- **Occupant Feedback Methods**
- Commissioning Persistence



Advanced Methods

- **Simulation-Assisted Commissioning Procedures**
- **Tune-Up Procedures Based on Calibrated Simulations**
- Semi-Automated, Component-Level Diagnostics

Functional Testing Guide for Air Handling Systems

…From the Fundamentals to the Field

Extensive guide provides a practical understanding of the fundamentals

Includes field tips for functional testing

Coupled to PG&E's Commissioning Test Protocol Library

Fills a need for functional testing education

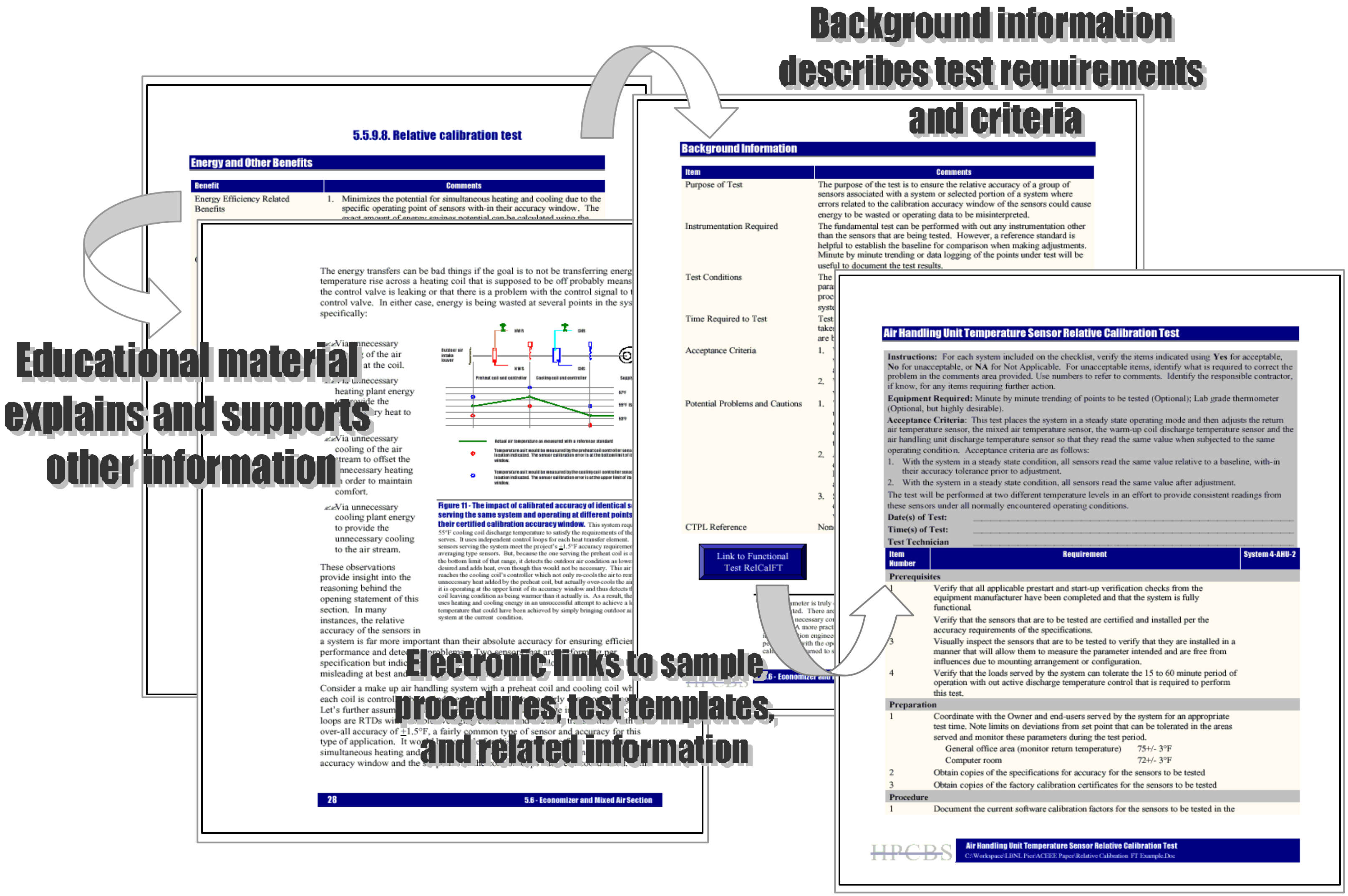
International dissemination

Functional Testing Guide for Air Handling Systems

Components included:

- Outdoor air intake
- Fan casing
- Economizer and mixed air
- Filtration
- Preheat
- Cooling
- Humidification
- Reheat
- Integrated operation & control
- Warm-up
- Fans and drives
- Distribution
- Terminal equipment
- Return, relief and exhaust
- Scrubbers
- Management and control of smoke and fire

Control System Design and Functional Test Guide



Evaluation of Diagnostic & Energy Information Tools

Tool reviews and comparisons are included for these features:

Metering and connectivity

Data visualization

Demand response

Remote control

Financial analysis

Guide to Emerging Diagnostic Tools for Large Commercial HVAC Systems

- Compares tools to detection and diagnosis of problems
- Helps users understand key capabilities
- Provides tool developers with feedback by identifying important features and needs for future research

		Data Acquisition	Archive and Pre-process	Detection	Diagnosis
ENFORMA		○	◐	○	○
UCB Tools		○	○	○	○
UT (PG&E)		○	◐	◐	○
WBD	WBE	●	●	●	○
	OA/E	●	●	●	●
PACRAT		●	●	●	●
EEM Suite		●	●	◐	○

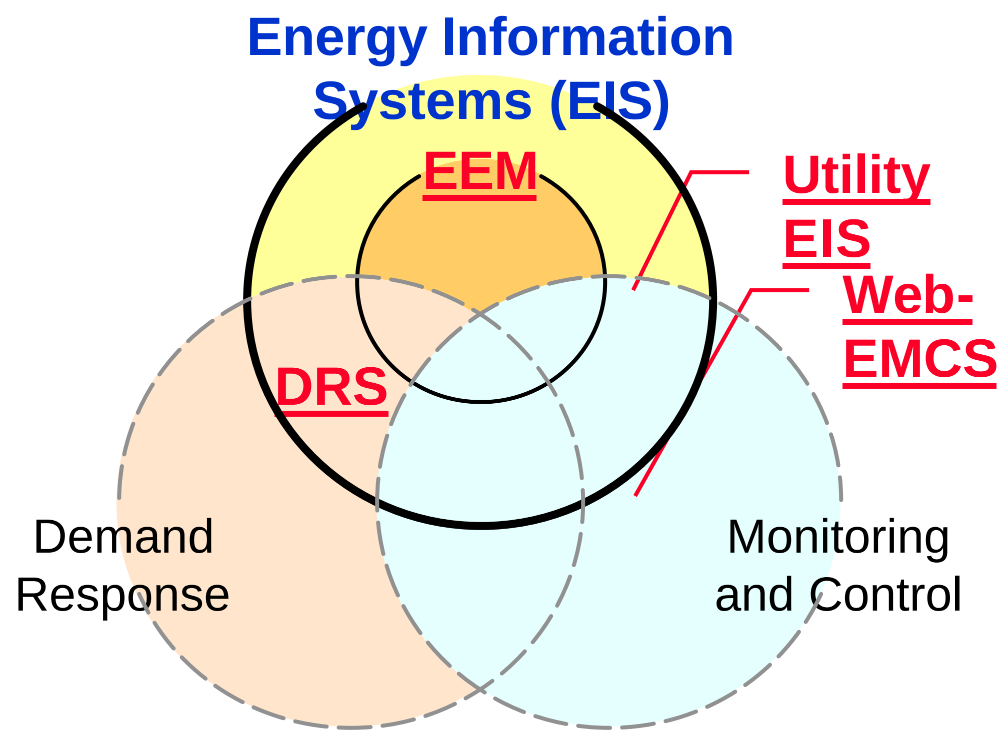
Automated	Partially automated	Manual
●	◐	○

Web-Based Energy Information Systems

Market for EIS is growing nation wide, and faster in California.

Customers are often overwhelmed by EIS feature and application options

Objective of this report is to provide a technical overview of currently available EIS products

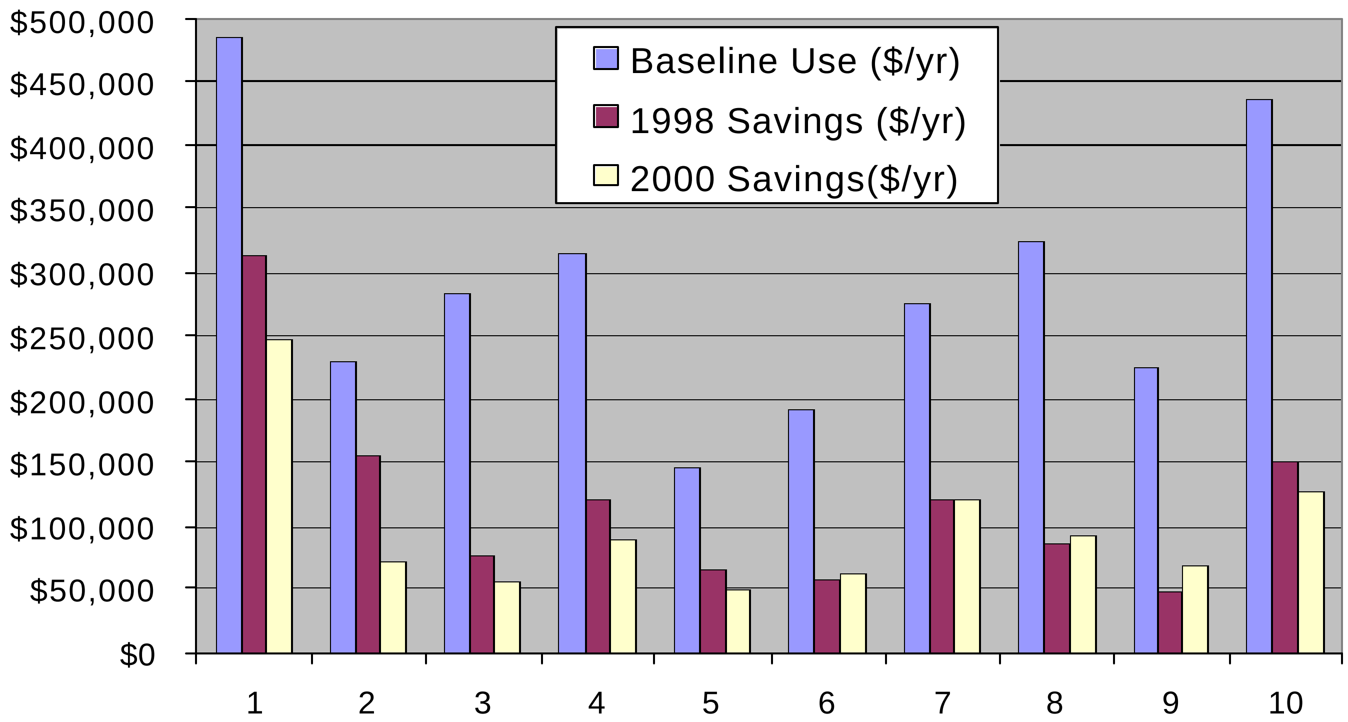


EIS Visualization & Analysis Features

Software product	Time series	Day overlay	Average	Highs/lows	Summary	Point overlay	X-Y scatter	3D chart	Load duration	Calendar profile	Aggregation	OAT plot	Per sqft	Forecasting
AMICOS	✓				✓	✓					✓			
Enerlink.net	✓		✓	✓	✓		✓	✓			✓	✓	✓	
Readmeter	✓			✓					✓		✓			
EP Web	✓		✓	✓	✓	✓		✓		✓				
Energy Profiler Online	✓	✓	✓	✓	✓	✓			✓		✓	✓		
Load Profiler	✓				✓	✓					✓	✓		✓
UtilityVison	✓	✓	✓	✓	✓	✓				✓	✓			
EEM Suite	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓	✓	✓
EnterpriseOne	✓	✓	✓		✓	✓	✓			✓		✓	✓	
Intelligent Use of Energy	✓	✓			✓	✓			✓		✓	✓		✓
IMDS/Electric Eye	✓	✓				✓	✓	✓				✓		

Commissioning Persistence

- **Are procedures implemented in commissioning defeated by operators?**
- **Persistence is a critical issue for building owners and public good programs**



Strategies for Improving Commissioning Persistence

For building owners, managers, and operators:

Design Review
Building Documentation
Operator Training
Building Benchmarking (Cal-Arch)
Energy Use Tracking (EIS)
Trend Data Analysis (Diagnostics)
Recommissioning

Persistence of Savings from Commissioning

	BUILDING (year commissioned)	DOCUMENTS			CENTRAL PLANT				AIR HANDLING AND DISTRIBUTION								PREFUNCTIONAL TESTS					OTHER		
		Commissioning report on site	Commissioning report used	Control sequences available	Chiller control	Cooling tower control	Boiler control	Hydronic control	Economizer control algorithm	Discharge air temperature reset	Simultaneous heating and cooling	VFD modulation	Dessicant cooling	Duct static pressure	Space temperature control	Terminal units	Piping and fitting problems	Valve modification	Wiring and instrumentation	Sensor placement or addition	Sensor error or failure	Scheduling	Skylight louver operation	Occupancy sensor
California	Lab and Office 1 (1996)	no	-	yes																				
California	Office Building 1 (1996)	no	-	yes																				
California	Office Building 2 (1996)	no	-	no																				
California	Office Building 3 (1996)	yes	yes	no																				
California	Office Buidling 4 (1994)	no	-																					
Pacific Northwest	Office Building 5 (1997)	no	-	yes																				
Pacific Northwest	Medical Facility 1 (1998)	yes	yes	yes																				
Pacific Northwest	Medical Facility 2 (1997)	yes	yes	yes																				
Pacific Northwest	Lab and Office 2 (1997)	no	-	yes																				
Pacific Northwest	Lab and Office 3 (2000)	no	-	no																				

Component-Level Diagnostics: Integrated Approach

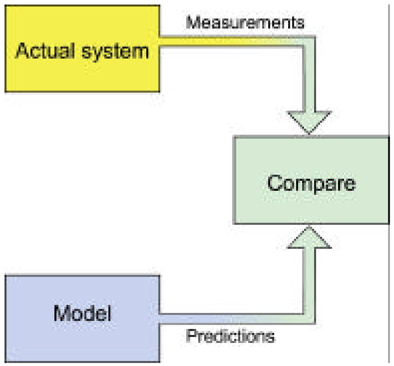
Use of models to represent correct operation:

Design
- configure model with design information

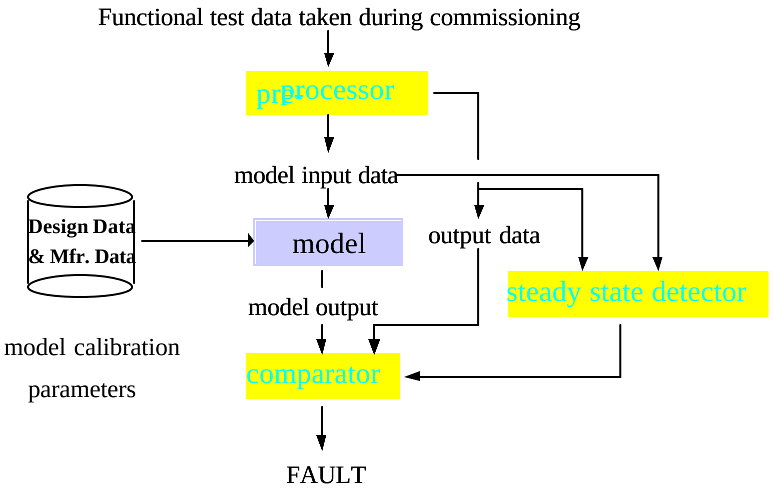
Commissioning
- verify performance during functional test
- fine tune model using functional test data

Operation
- use model for online performance monitoring

Model-based Component-level Fault Detection



- Models of AHU and chiller in SPARK
- Methods for active tests & passive monitoring in C++
- Off-line testing using data from IEC and CA office buildings
- Interfaces for on-line operation under development



Commissioning and Diagnostics

Next Steps

— CEC

- **Performance Monitoring Specifications**
- **Demand Response testing and development**

— IEA Annex 40

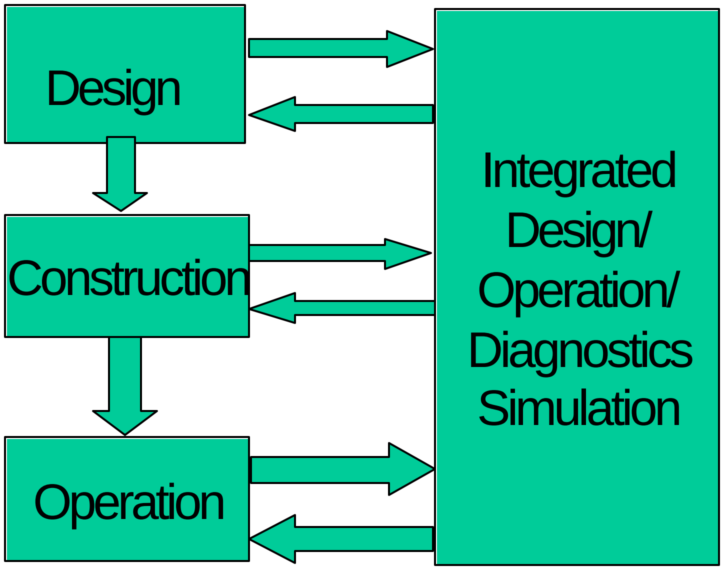
- **Automated FDD with international testing**

— ASERTI

- **FT Guide dissemination and feedback**
- **Educational material**
- **Explore opportunities to automate tests**

— SMUD

- **Study of 8 SMUD sites, interest from CCC**



Element 6: Energy and Indoor Environmental Quality (IEQ) in Relocatable Classrooms (RCs)

Goals

- Quantify and demonstrate opportunity for simultaneous energy savings and IEQ improvements
- Advance energy & IEQ technologies for RCs

RCs at an Elementary School

Anticipated Long-Term Benefits

- Energy savings
- Improved health and learning

Team

- LBNL
- Davis Energy Group

Technical Tasks

Energy and IEQ Field Studies

Construct, site, and monitor RCs with advanced energy and IEQ attributes.

- Advanced Hybrid HVAC technology
  - Indirect-Direct Evap. Cooling
  - Natural gas hydronic heating
- Assess Energy and IEQ benefits of advanced hybrid HVAC system
- Assess benefits of material testing and selection for low pollutant emissions

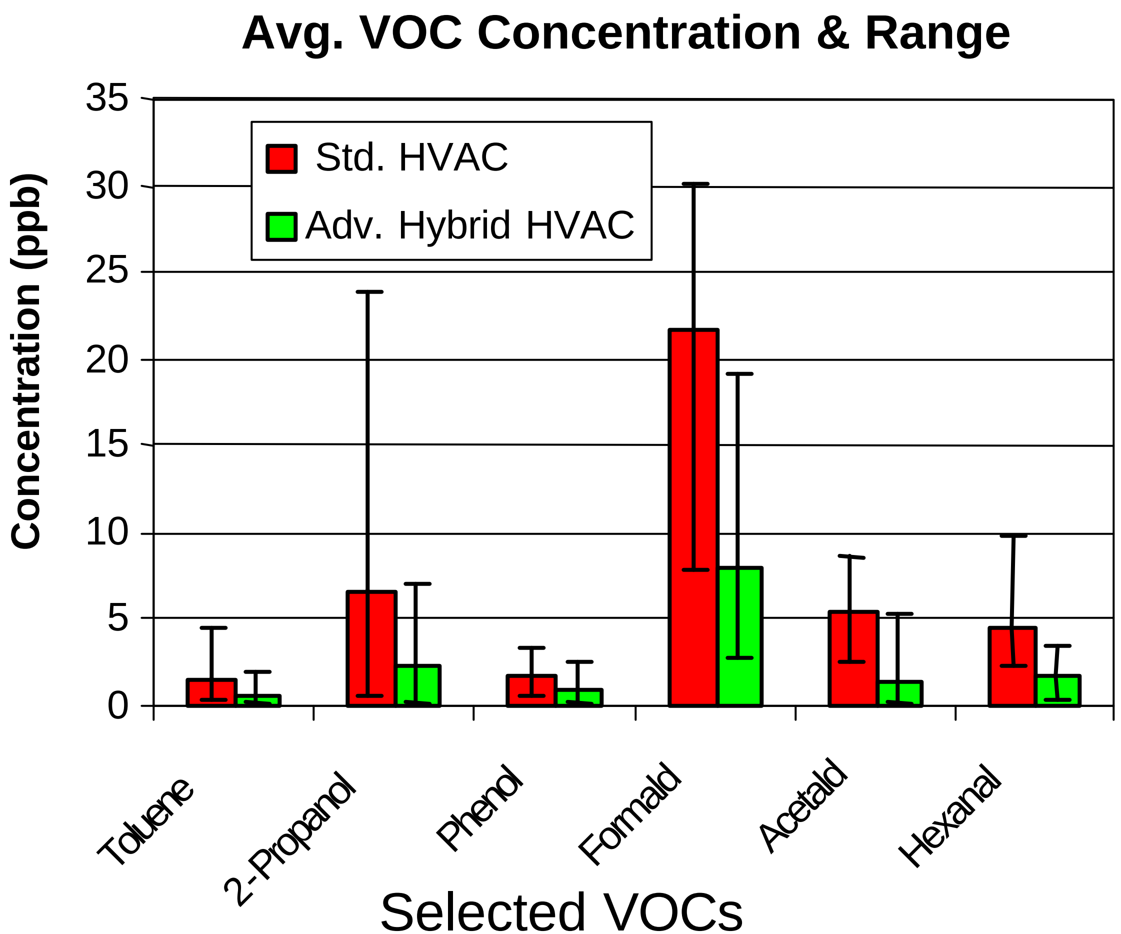
Energy simulations (DOE-2)

- Develop DOE-2 models for RCs
- Calibrate models using field data from Energy and IEQ study
- Predict statewide energy savings potential from advanced HVAC system

Key Findings

- **Advanced Hybrid HVAC**
  - —**Saved substantial energy**
  - —**Provided thermal conditioning comparable to conventional HPAC systems**
  - —**Significantly reduced indoor pollutants**
- **Improved ventilation was more important than low-VOC building materials selection (may be manufacturer specific)**
- It is practical to simultaneously reduce energy expenditure and improve IEQ

Volatile Organic Compound Concentrations (VOCs) Reduction in Cooling Season

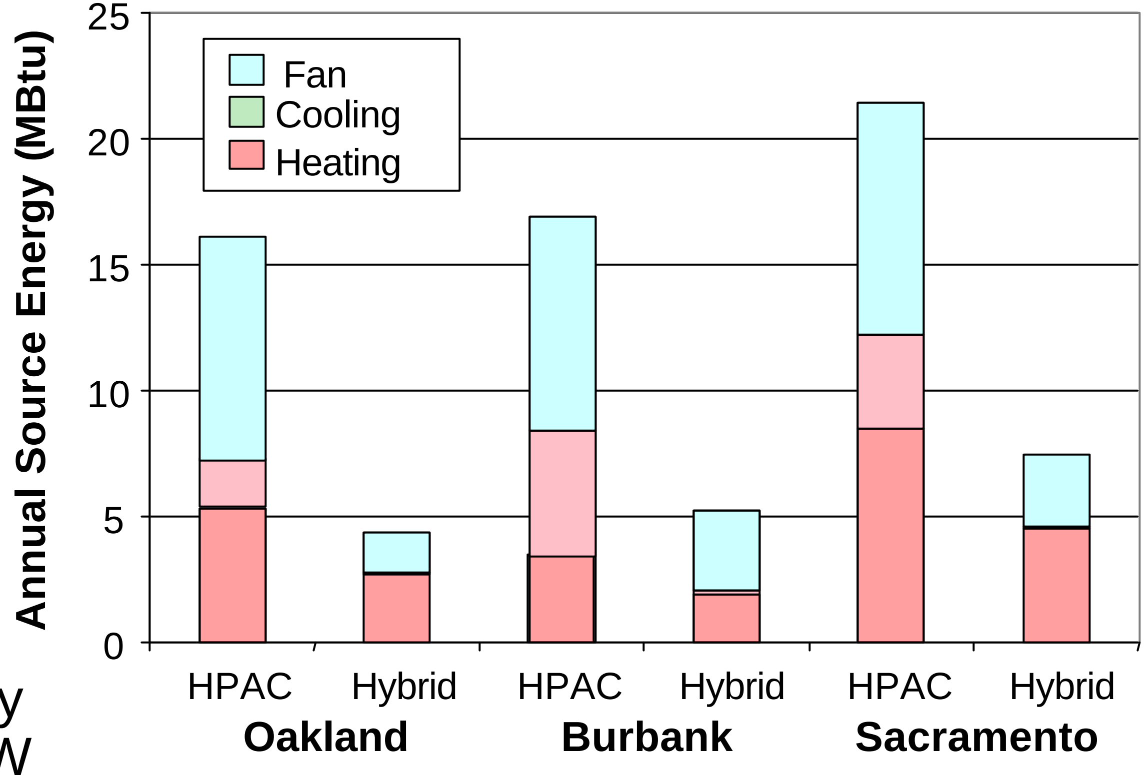


Findings

- Most concentrations were low in all RCs
- Formaldehyde occasionally exceeded OEHHA chronic non-cancer Reference Exposure Limit: 27 ppb for 8-hours
- Lower VOCs with advanced hybrid HVAC

Predicted Energy Comparison DOE-2 Energy Simulations Calibrated Using Field Data

- Statewide yearly savings from use of advanced hybrid HVAC in 4,000 new RCs:



- save 6,000 MWh electricity
- reduce winter peak 24 MW
- reduce summer peak 13 MW
- increase natural gas 1020 Mbtu
- reduce school district operating costs by $880,000

Recommendations*

- Encourage and stimulate building design and operation for simultaneous energy savings and IEQ improvements
  - — Strengthen market pull through better quantification of benefits to occupants (e.g., improved health) and to employers and institutions (e.g., reduced absence, financial benefits)
  - — Aggressively communicate results to stakeholders
  - — Improve associated standards and guidelines
- Continue development of low-energy, IEQ-superior HVAC
  - — Technologies must be considered practical by school districts
  - — Different technologies for different climates
- Improve ventilation system controls for schools
  - — Don't rely on teacher but keep controls simple

*Recommendations applicable for many types of buildings

Questions?

More Information:

1. **CDs with key deliverables**
2. **Project Brochures**
3. **Project Website:**
   http://buildings.lbl.gov/hpcbs